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THE
GEOLOGICAL MAGAZINE
VOLUME LVIII.

No. I.—JANUARY, 1921.

EDITORIAL NOTES.

IN commencing a new volume the Editors desire to convey their thanks for the generous support they have received during the past year from contributors and subscribers. They still, however, find themselves faced with financial difficulties of a serious nature, arising from the continued increase in the cost of production. For the first half of 1920 a small profit was made, but this was almost wiped out by a considerable further rise in the cost of printing in the middle of the year. An important item in expenses is the cost of plates, and they are regretfully compelled to inform their contributors that it will under present conditions be impossible to produce plates at the expense of the Magazine. They feel sure, however, that their friends will not hesitate to incur the expense involved in meeting the cost of the illustrations, which are so necessary to bring out the full value of their papers. Many of them have done so voluntarily in the past, and the Editors trust that even under the present conditions, that bear so heavily on people of moderate means, they will be able to continue to provide them.

* * * * *

WHILE on this subject we should like also to take our readers and subscribers into our confidence and to inform them that although arrangements have been made which, at any rate, ensure continuance for 1921, there are limits to this sort of thing. In the first place it should be made quite clear that the Editors receive no remuneration, and are, as a matter of fact, slightly out of pocket as the result of their labours. Nevertheless, they do their work gladly in the interests of geological science, which they earnestly hope is really benefited by the continued existence of the Magazine, and they would feel the greatest regret if they were compelled by force of circumstances to relinquish their self-imposed labour of love. There are in hand at the present time a very large number of important papers awaiting publication, forming the firstfruits of the renewal of geological activity since the War; interest in many old problems has revived, and many new ones await solution. At the present time the prospects of our science are bright, and the Editors appeal earnestly to all its votaries to support them in their endeavours to further its progress. The Geological Society of America set an excellent example a year ago by guaranteeing forty new subscriptions to the Magazine, an act which has been the main factor making possible its continuance

during 1920, and it may be suggested that if each of our readers could obtain even one new subscriber the future of the Magazine would be assured.

* * * * *

We have received a copy of the Annual Return made by order of the Trustees of the British Museum, showing the work performed by the Staff of the various departments, the visits made by the public, and the objects acquired by purchase and donation during the year 1919, with the income and expenditure for this great national institution, Bloomsbury, and its branch the Natural History Museum, Cromwell Road, South Kensington. The number of visitors to the Natural History collections during 1919 was 455,736.

* * * * *

Geologists will be glad to learn that the collection of fossil corals and brachiopods from the Carboniferous Limestone of Britain and Belgium, made by the late Dr. Arthur Vaughan, has been secured for the Geological Department of the Museum. Owing to the wide distribution of our armies during the War, and of scattered British subjects in foreign lands, numerous additions have been made to the foreign collections of the Geological Department. Vertebrate remains have been presented from Afghanistan, Salonika, Egypt, the Sudan, Switzerland, Sinai, and California; and invertebrate fossils and plants from New Zealand, Australia, Arabia, Peru, Hanover, Canada, India, Persia, Ypres (Flanders), Malta, Taranto (Italy), Jamaica, Sardinia, the United States, Colorado, Dalecarlia (Sweden), Central Arabia, Esthonia, Samara, Russia, and Manchuria.

* * * * *

A great work of national importance carried on in the Geological Department is Mr. C. Davies Sherborn's Index of the Genera and Species of Animals. During the past three years considerable progress has been made with this Index, under Mr. Sherborn's charge, and some 90,000 references have been added to the manuscript. The letter "T" of authors has now been reached. The manuscript has been continuously and extensively consulted by the staff and by students, whilst many inquiries have been answered by Mr. Sherborn in correspondence, which has been greatly increased owing to the many practical uses to which natural science is now applied, necessitating accurate nomenclature of the animals referred to. Further publication by Mr. Sherborn of bibliographic data has not been necessary during the past year; but a large draught has been made upon his manuscript by Mr. Gregory Mathews and Mr. Tom Iredale for their *Birds of Australia* and *Mollusca of Australia*.

ORIGINAL ARTICLES.

On the Geological Features of the Oil Region in the Northern Punjab (British India)

By H. Preiswerk, Basle.

(PLATE I.)

Introduction.
A. Rawalpindi Plateau (Potwár).
B. The Oil Region of Jaba in the Western Salt Range.
C. The Burning Gases of Jawalamukhi, Kangra District.

Introduction.

In the great chains of mountains belonging to the Alpine system, stretching from the Armenian upland through Eastern Mesopotamia, Western and Southern Persia, and Baluchistan up to the Indus, then—in a great curve—encircling the Indian tableland in the Kirthar and Suleiman ranges and the Himalayas, then in the east turning south to Burma—there are several regions rich in oil, following the foot of the mountain-ranges on the border of the plains extending in front to the south. The most important of these oil-regions arrange themselves into three chief groups: the Mesopotamian–Persian region, the Baluchistan–Punjab region, and the Burmese region.

The Mesopotamian–Persian region and the Punjab region, summarily called by Sir T. H. Holland the " Iranian System ", show a striking geological concordance in the occurrence of oil-shows. In both regions all oil-outcrops follow the border of large ranges of Eocene Nummulitic limestones, which both in Persia and in all oil-places in the Punjab that I have seen are overlain by variegated gypsiferous marls. Also the cellular limestone, which is so widely spread in the Punjab as a contact layer between the Nummulitic limestones and the gypsiferous clays, and which is probably of importance as an oil-bearing horizon, occurs again in the Persian oil-zones. As to the Persian oil-region, gypsiferous marls lying immediately over the Nummulitic limestones are considered to be the oil-bearers.

It is a striking coincidence that in the Punjab, too, the contact-zone between Nummulitic limestones and particoloured gypsiferous marls bears the oil-shows.

This stratigraphical horizon is also of eminent importance for the oil-bearing of the two regions. Its outcrop in the Punjab is shown on the sketch-map, Fig. 1. This also shows the chief oil-zones, from which we can clearly recognize that the oil-shows are strictly confined to the horizon just mentioned.

A. THE RAWALPINDI PLATEAU (Potwár).

The level plateau of Rawalpindi is limited by a steep range of Nummulitic limestone—8 miles north of the town. This range

stretches in a straight line from the Murree Mountains in the W.S.W. direction to the Margala Pass. Wynne calls the range the Margala Hills. They are the first range of the Hindukush. The Hindukush and the mountain ranges lying in front of it are composed of Archæan, Palæozoic, and Mesozoic formations. In the more southern ranges the younger formations predominate. In the most southerly range, the Margala Hills, we find Eocene Nummulitic limestone, which by its capacity for resistance forms a border range rising very

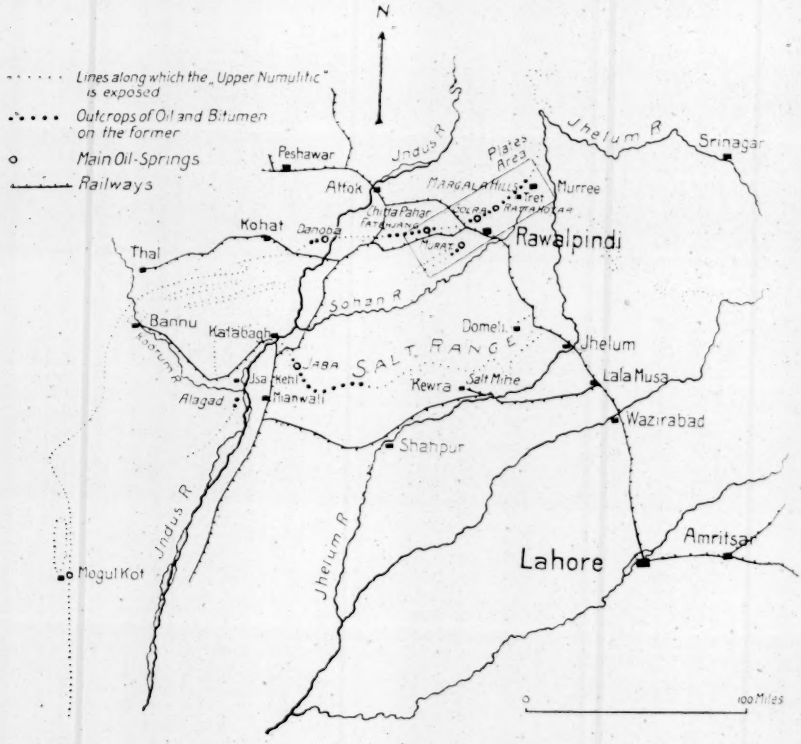


Fig. 1

suddenly out of the plain. The Eocene is not everywhere in its lower parts developed as Nummulitic limestone. Thus we find in the Trans-Indus district Eocene clays with gypsum and enormous masses of rock salt, below the Nummulitic limestones.[1] The Nummulitic limestones are partially bituminous, especially in their uppermost beds, which often consist of nodular limestones interbedded with clay. There, too, we find oil-shows.

[1] A. B. Wynne, Records of the Geol. Surv. of India, vol. x, p. 116.

Between the Nummulitic limestones at the base, and the immense sandstone beds following next above, there occurs with great regularity that very formation in which we find the oil-springs. It is called "Upper Nummulitic" by Wynne, and may be homotaxial with the "Kuldana beds" of Middlemiss.[1] It contains variegated, chiefly red or brown, clays and marls with gypsum and layers of porous or compact limestones and beds full of Nummulites and *Assilina*. Cellular limestones (cargneule) are often found at their base, forming the top of the compact Nummulitic limestone. In some parts these Upper Nummulitic beds have a thickness of several hundred metres.

The plateau of Rawalpindi (see Plate I) itself consists of red and gray sandstones, reddish clays, and conglomerates in the younger parts. These formations represent the middle and upper Tertiary: the Murree beds and the Siwalik group. We find them everywhere in the environs of Pindi, unless they are covered by the often thick conglomerates and loess-like formations of the diluvium and alluvium.

The separation between limestone hills on the one hand and the sandstone region of the plain on the other is not absolutely sharp: bands of sandstone occur also as synclines infolded with the limestones, such as the sandstone district of Sang-Jani, and also Nummulitic limestones rise as anticlines out of the sandstone region of the plain. Such "outliers" (Wynne) are e.g. the limestone hills north of Kutbal, which form the eastern branch of the Chitta Pahar range. They continue to the east as the anticline of Golra, which near Saidpur comes closer again to the Nummulitic limestone hills. At Golra and at other places in this advanced anticline the massive Nummulitic limestones of the anticlinal core disappear below the variegated gypsiferous marls of the Upper Nummulitic. It is in these very places that the oil-springs appear. Precisely the same tectonic features give rise to the oil-springs of Gunda, near Fatehjang.

A yet more striking and isolated outlier is the Kairi-Murat ridge, south-west of Rawalpindi, where the Nummulitic limestone of the anticlinal core rises out of the plain as a steep and long limestone ridge. At the east end of the ridge the Nummulitic limestone sinks in the axis of the anticline below the marls of the Upper Nummulitic, and these farther east below the sandstones of the Murree beds. Here, too, the oil appears above the Nummulitic limestone as soon as it is covered by the Upper Nummulitic clays.

All the Tertiary formations of the environs of Rawalpindi are intensely folded and squeezed together into tightly compressed folds. The dip is almost always very steep, and in the axes of the folds isoclinal structure is frequent. In the limestone ranges we find here and there overthrusts to the south. The sandstones of

[1] Memoirs Geol. Surv. of India, vol. xxvi, 1896, p. 42.

the plain are hardly less intensely folded than the limestone hills. But the sandstone folds have been almost wholly removed by erosion.

Taking into account the great thickness of the sandstones and the steep folding, we must suppose that the Nummulitic limestones and the oil-bearing beds covering them are mostly some miles below the surface in the plain about Rawalpindi. Places where they might be expected to exist at an attainable depth have up to this time not been found, excepting the east end of the Kairi-Murat ridge.

About 50 miles south of the Kairi-Murat ridge the Nummulitic limestones rise again from below the sandstones of the Murree beds, on the northern border of the Salt Range. It forms the north side of this long drawn-out range of mountains for more than a hundred miles, and still continues in the Trans-Indus extension of the Salt Range (see Fig. 1). In the eastern and central parts of the Salt Range no gypsiferous marls occur between the Nummulitic limestones and the overlying Murree sandstones. Only in the western part the marls appear again, together with cellular limestones (cargneule). And here, too, the oil-springs of Jaba appear, in the roof of the Nummulitic limestones, just as in the district of Rawalpindi and Fatehjang. In the same horizon south-east of Jaba a series of pitch occurrences is reported. We further have to mention the pitch-beds of Alagad, situated in the part of the Salt Range lying west of the Indus.

Further details of the stratigraphical development of the oil-horizon in the Salt Range are given later.

The structure of the western Salt Range differs from that of the ranges near Rawalpindi insomuch as the folds of the Salt Range are less tightly compressed and more normally built, therefore showing on the average a smaller inclination of the strata.

In 1914 R. Zuber[1] published some notes referring partly to the same districts which I have examined. Zuber is of opinion that the different Nummulitic limestone ranges of the Potwár (outliers, Wynne) are thrust over the Murree beds, and now represent: "durch spätere Denudation zerrissene Ueberreste der Hazar-Decken." The same would be the case with the Salt Range, the strata of which are probably thrust over the Tertiary salt-formation. I do not want to discuss the new points of view Zuber has on the problem of the Salt Range, but only to put forward an opinion differing from Zuber's idea about the structure of the Nummulitic limestone ranges of the Potwár, especially of the Chitta Pahar and of the Kairi-Murat ridge, which I know more thoroughly. I certainly must agree with Zuber that at the south margin of the steep limestone hills of the Margala Hills overthrusts can be observed by which the Murree and Kuldana beds are overlain by the older

[1] Rudolf Zuber, "Beiträge zur Geologie des Punjab": Jahrbuch k.k. geol. Reichsanstalt, Wien, 1914, pp. 327–56.

Nummulitic limestones and perhaps also by Mesozoic limestones. A nice example of this is furnished by the limestone plateau projecting into the plain to the west of Saidpur, under the base of which sandstones and red clays of the younger formations disappear, while following the general strike of the range. I also know quite well that nice turn of the strata in the Nummulitic limestone (turning south) of the Kairi-Murat ridge which may be so well recognized from the Forest Bungalow of Murat. The only question is if those indications of north–south directed overthrusts have more than local importance, and if, on account of that, we are justified in considering mountain ranges like the Kairi-Murat ridge as remainders of an overthrust. I cannot answer this question in the affirmative. Wherever I had an opportunity of making exact observations, viz. in the eastern part of the Kairi-Murat ridge and in that part of the Chitta Pahar which runs out to Golra, I came to the conclusion that the Nummulitic limestone ranges of these outliers correspond to fold-axes of autochthonous anticlines. I, therefore, come back—contrary to Zuber's idea—to the view held by Wynne, who has expressed it not quite so distinctly in his sections, but very clearly on his map of the north-west Punjab.[1]

The difference of opinion is best illustrated by comparing Zuber's sections: p. 338, figs. 2–5, and p. 343, fig. 9, with my sections IV–X, Plate I. The reasons which induced me to suppose autochthonous anticlines are:—

(*a*) The limestone ridges interrupting the uniform sandstone district of the Murree beds are not to be considered as erratic masses above the Murree beds, but as in stratigraphical normal connexion with them, the limestone core of the anticline being almost regularly accompanied on either side by variegated, often oil-bearing marls and clays of the Kuldana series (Upper Nummulitic) and separated by them from the younger Murree beds.

(*b*) The soft Kuldana beds would certainly not have remained in their normal position if forming the top of overthrust limestone-folds.

(*c*) Further, the massive beds of limestone of Sihala (Point 2207, Zuber, fig. 4) cannot be considered as an isolated overthrust relict. They form a member of an uninterrupted chain of several limestone outcrops, accompanied by Kuldana beds, which can be seen following in a straight line the strike-direction from Golra as far as Chitta Pahar, where they unite with the chief mass of the Nummulitic limestones (see Plate I). We can easily understand this range of limestone ridges as separate cores of a steep, compressed anticline; but we can hardly believe it to be the front boundary of an overthrust range.

The fact that the Kuldana beds frequently and often on both sides dip in under the limestone ridges is explained by the reflection that

[1] Map 1 inch = 8 miles, Records Geol. Surv. India, vol. x.

the soft Kuldana beds escape erosion and become visible especially where they are protected by swellings of the folded limestone core of the anticline (compare sketch Fig. 2).

Description of the Oil Localities.

1, Golra (Rawalpindi District). 2, Saidpur-Ratta Hotar. 3, Tret-Murree. 4, Fatehjang. 5, Sil and Basala Rivers, near Murat. 6, The Rock-Tar at Lundegar.

The six oil-fields I have visited belong to two Nummulitic limestone ranges :—

(*a*) The border ranges north of the Rawalpindi plateau : Margala Hills and Chitta Pahar (Sections I–IV).

(*b*) The Kairi-Murdi ridge, near Murat, south-west of Rawalpindi (Sections V and VI).

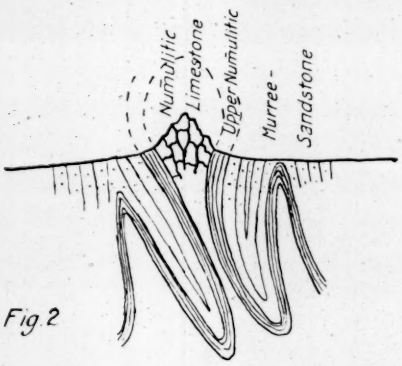


Fig. 2

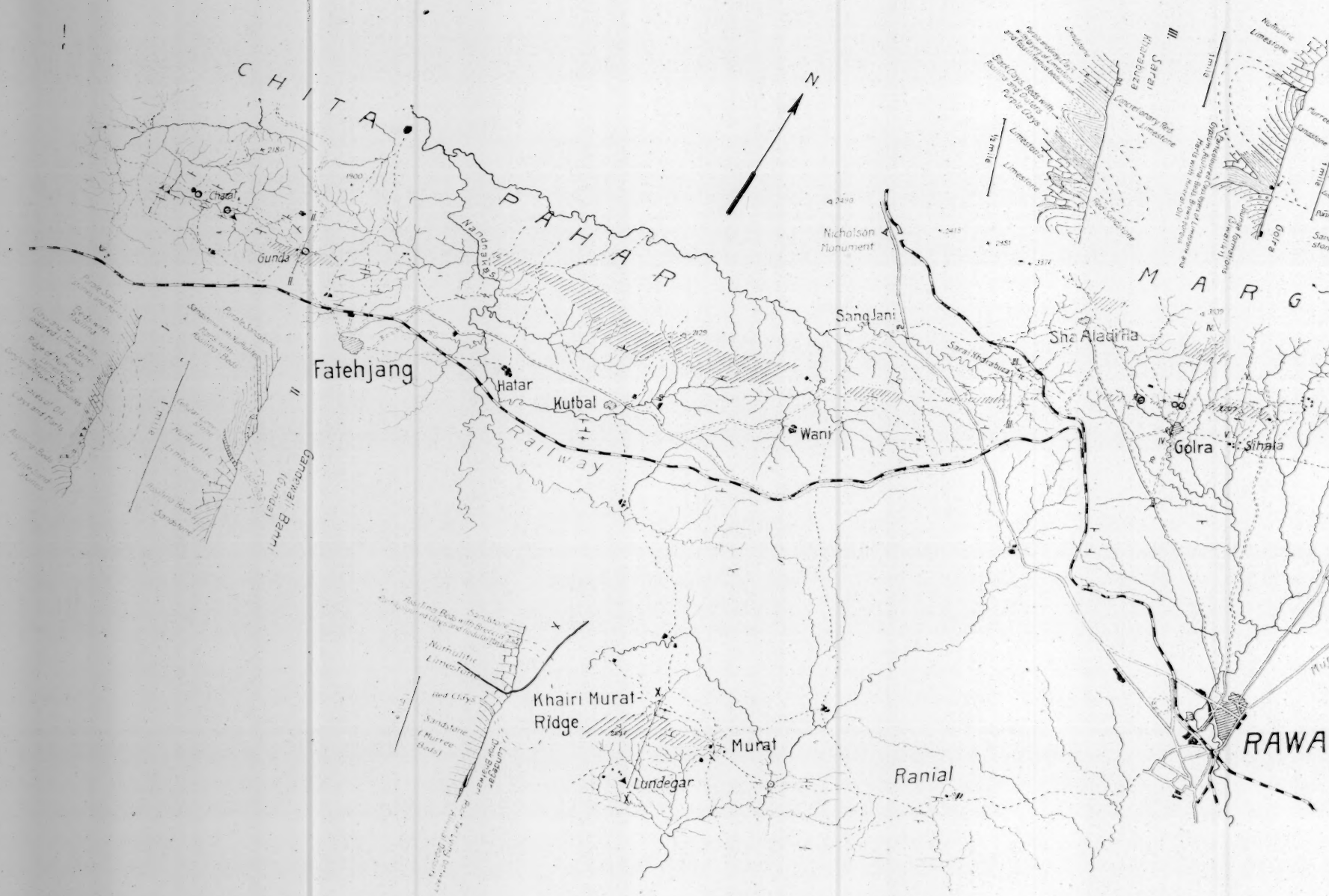
1. GOLRA.

The Oil-springs.

To the north and west of Golra we find three oil-springs, the most westerly of which is about 2 miles, the most easterly nearly 3 miles distant from the railway station of Golra Junction. The three oil-springs lie in a straight line, running N. 60° E., and there is a distance of something more than one mile between the most westerly and the most easterly of the springs (compare Plate I).

The most important of the three springs near Golra village is the one farthest to the east. It is situated on a small river, which has cut itself 4 metres deep into the plateau, about 400 metres to the north-east of the bathing-place, which lies in the garden of the Hindu Padri : Mamt Advita Nand.

The oil flows out in drops into the little brook, together with water containing sulphuretted hydrogen. The main spring rises a little above water-level on the western bank of the brook. In a dark-brown substance mixed with clayey and tarry material there is an excavation which is filled with oil, and—when exhausted—fills itself again daily. The oil is somewhat thick and of a dark-brown colour.


CHITA PAHAR
N.
Chaal
Gunda
Fatehjang
Hatar
Kutbal
Railway
Wani
Sanglani
Nicholson Monument
Sha Alamria
Golra
Sihala
Khairi Murat Ridge
Murat
Lundegar
Ranial
RAWA
Nammal Lake
Gandhwal Bann (Gundal)
Sangjani Series
Murree Series
Kamlial Series
Nummulitic Limestone
Sandstone (Murree Beds)
Limestone
Sandstone
Shales
Coal
Gypsum
Salt
Fossils
Siwalik Boulder Bed
Kamlial Sandstone
Murree Sandstone
Murree Shales
Kamlial Shales
Sangjani Sandstone
Sangjani Shales
Nummulitic Limestone
Sangjani Limestone
Murree Limestone
Kamlial Limestone
Sangjani Coal
Murree Coal
Kamlial Coal
Gypsum
Salt
Fossils
Siwalik Boulder Bed
Kamlial Sandstone
Murree Sandstone
Murree Shales
Kamlial Shales
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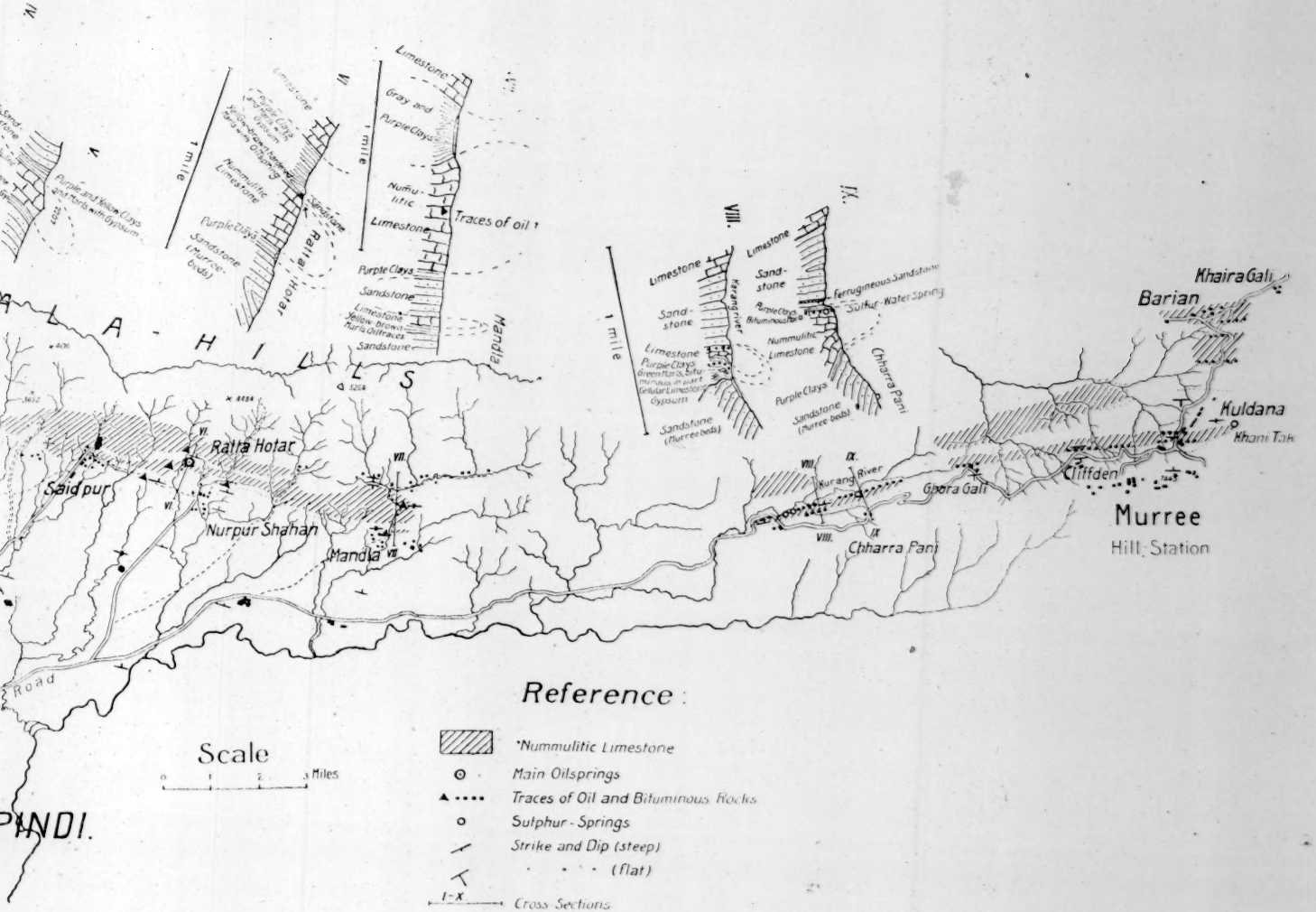
Murree Coal
Kamlial Coal


Limestone
Gray and Purple Clays
Nummulitic Limestone
Traces of oil ?
Purple Clays
Sandstone
Limestone
Sandstone
1 mile
Mandla
Purple and Yellow Clays and Marls with Gypsum
Sandstone (Murree beds)
Purple Clays
Nummulitic Limestone
Limestone
Sandstone
1 mile
Railway Inlier
Limestone
Sand-stone
Purple Clays Bituminous
Ferrugineous Sandstone
Sulfur-Water Spring
Nummulitic Limestone
Purple Clays
Sandstone (Murree beds)
Chharra Pani
1 mile
Limestone
Purple Clays Green Marls, Siliceous in part, Cellular Limestone & Gypsum
Sandstone (Murree beds)
Khaira Gali
Barian
Kuldana
Khanni Tak
Cliffden
Murree
Hill Station
Ghora Gali
Kurang River
Chharra Pani
Ratta Hotar
Said pur
Nurpur Shahan
Mandla
Road
SALT RANGE HILLS
PINDI.
Reference :
*Nummulitic Limestone
Main Oilsprings
Traces of Oil and Bituminous Rocks
Sulphur-Springs
Strike and Dip (steep)
(flat)
I-X Cross Sections
Scale
Miles

I have been told at the Rawalpindi gas-works that they yearly obtained about six barrels of oil from Golra. Together with other oil and wood it is used in the manufacture of gas and of tar.

The second oil-spring, hardly 100 metres farther to the west, lies in the bed of a brook parallel to the first. There, too, we notice in various places oil flowing into the water of the brook together with springs of sulphuretted hydrogen. The main oil-spring is only a few feet above the brook in a little channel running east. It is a cavity filled with oil. From time to time gas-bubbles rise from the oil.

The third and most westerly oil-spring is situated near the Mosque of Dheri Shah Sikandar Wali. To the east of this building, on the left bank of the river, appear limestones with clayey marls richly impregnated with oil.

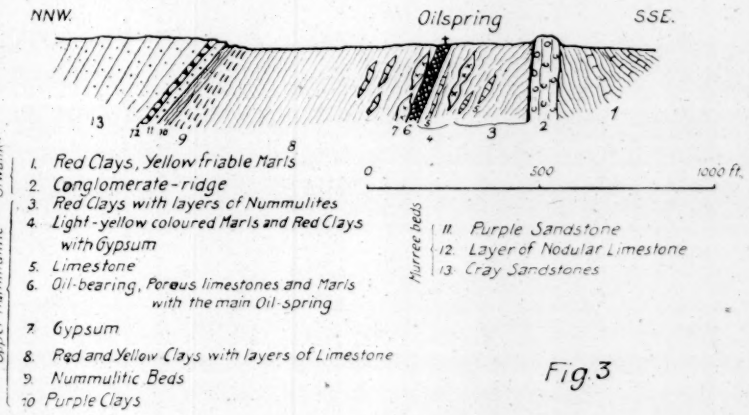


Fig 3

Some oil is also said to flow out of a channel halfway between the main oil-springs of Golra and of the Mosque. There was, however, nothing to be seen at the time of my visit.

Geological Structure of the Neighbourhood of the Oil-springs.

1. *Near the Oil-springs.*—The section (Fig. 3) informs us about the nature and arrangement of the rocks in the immediate neighbourhood of the main oil-springs north of Golra.

Many of the rocks appearing near the main spring on the brook are very bituminous, and the thickness of the bituminous beds may be estimated at 40 feet.

The oil-bearing rocks are essentially porous and crumbly limestones and calcareous marls as well as gypsum. Here and there we find beautiful crystals of aragonite in the oil-marls. The strata have an inclination of 60° on an average, towards N.N.W. Towards the lower end of the valley, below the oil-bearing beds, follow red and light yellow coloured marls and clays, about 50 m. thick,

with layers of compact limestone and gypsum and limy beds rich in Nummulites. The strata, which dip north, show lower angles of inclination, down to 35° towards the south. Near the end of the valley these clays sharply break up on the perpendicular strata of a conglomeratic ridge (compare Fig. 3). The conglomerates chiefly consist of large boulders of grey and yellow limestone. These conglomerates might belong to the Upper Siwalik formation. To the south of the ridge very steep clays and marls follow, quite different from those near the oil-springs. Farther away from the ridge the strata quickly become more level, and disappear below the alluvium. Thus the environs of the conglomeratic ridge appear as the axis of an anticline, the crest of which shows an important dislocation.

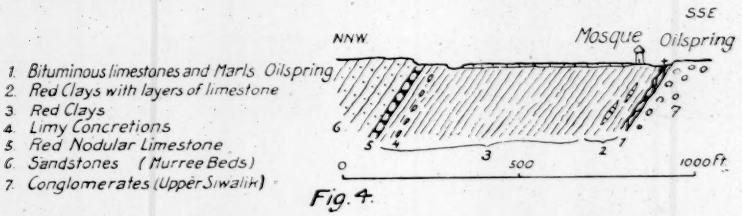


Fig. 4.

Turning to the north from the oil-beds to the hanging-beds, we first meet red and yellow clays with lenses of Nummulitic limestone and gypsum. The clays are more than 100 metres thick, and similar to those below the oil-bearing rocks. They are irregularly disposed, in certain parts steeper, in others more level. About 200 metres to the north of the oil-shows a hard and ridge-like purple sandstone crosses the bed of the river. Purple clay and yellow nummulitic layers, which are extremely rich in fossils, appear below the sandstone, representing the uppermost part of the nummulitic formation. The purple sandstone of the boundary dips north at 45°. It is covered by a bed of characteristic red nodular limestone. Such nodular limestones are often significant for the boundary between the Upper Nummulitic and the Murree beds. Farther to the north we notice now the monotonous sandstones of the Murree beds.

The section through the oil-spring near the Mosque Dheri Shah Sikandar Wali is represented on Fig. 4. The conditions here are similar to those of the main spring to the east. There, too, the oil flows out from layers of limestone in the variegated clays, which also here—in a distance of 200 metres from the oil-beds—are covered by the sandstones of the Murree beds. The sandstones dip rather more steeply than on the east, perhaps 60°, whilst the clays have only an inclination to the north of 50°. The southern part of the section is only exposed to a small extent. The variegated clays with their layers of limestone and the oil-springs are cut off in the south from the coarse conglomerates on the river near the

Mosque. These conglomerates are very similar to those in the ridge near the eastern main oil-spring.

From what we have seen so far *the three oil-springs near Golra have the same geological situation.* They all appear in the lower parts of the variegated clays. These variegated, nummulitic, and gypsum-bearing clays—according to Wynne belonging to the "Upper Nummulitic"—can be traced for more than a mile distance near the oil-springs of Golra, with a breadth of 300 metres. They dip to the north at about 60°. In the middle, between the eastern and western springs, however, nearly vertical bedding is found. Here, near the graves of the Mohammedans on the hill, they are pierced by a larger mass of limestone (Plate I).

2. *On the Surroundings of Golra.*—We acquire a general knowledge of the geological structure by tracing the section through the main springs in the north of Golra farther north (Section IV, Plate I). From the first appearance of the sandstones we meet—for a whole mile, as far as the foot of the steep limestone hills—nothing else but sandstones with scanty beds of clay, the strata mostly dipping very steeply. At the foot of the first hill of the mountains the sandstone, however, forms a syncline which is more flat, and afterwards the red clays of the "Upper Nummulitic" appear, and still more to the north the enormous masses of the "Hill-Nummulitic limestone" with still older—according to Wynne—Mesozoic limestones in perpendicular strata or even turned over the "Upper Nummulitic" by inversion.

The Section IV (Plate I) tries to explain the tectonic conditions of the four formations: the Nummulitic Limestone, the Upper Nummulitic, the Murree Sandstone, and the later (Siwalik) conglomerates and marls. According to this section there are, between Golra and the top of the limestone hills, two anticlines, the core of which is formed by Nummulitic limestones. In the northern anticline the limestone itself appears, forming the mountain range, whilst in the southern anticline it is hidden, at least near the oil-springs, below the Upper Nummulitic. The Upper Nummulitic appears in the northern anticline as a reduced and overturned south flank, in the southern anticline as a normal north flank. But towards the south it does not continue below the normal hanging Murree beds, but is cut off from the younger conglomerates by unconformity. From this we see that an important dislocation runs in the direction of the axis of the anticline, which has lowered the south flank, or rather, has overturned the north flank over the south flank. The Murree beds form a proper syncline, which, however, is very unsymmetrically built, its axis being displaced to the north. The flank of the syncline, which is turned towards the mountains, must therefore be either completely crushed or covered by the overturned and anticlinal Hill-Nummulitic limestones.

To the south of the line of dislocation, near the oil-springs,

no Murree sandstones appear, but only younger conglomerates and marls, which might belong to the Upper Siwalik or even to the older Diluvium. The absence of the thick Murree formation shows that we have to deal with a very remarkable dislocation, which I have looked upon as a fracture and steep overthrust of the crest of the anticline.

Owing to the steep dip of the Siwalik conglomerates we must conclude that the folding of the rocks has been going on up to the youngest geological periods.

I have further examined the formations running west and east from the section of the Golra oil-spring. First the anticline of Golra : The anticlinal axis is soon covered by alluvium to the east of the main oil-springs. About half a mile to the east outcrops show again, near Hill 2207 (Section V, Plate I). This hill has already been mentioned on p. 7. Here the anticline is strongly pushed up. The massive Nummulitic limestones, which form the core of the anticline, appear on the steep Hill 2207, running along the crest, accompanied on both sides by the overlying Upper Nummulitic and the Murree beds. The Upper Nummulitic is here completely eroded away on the anticlinal axis. The strata are everywhere very steep. The south flank is overturned, and dips north at 60°. The limestones in the axis of the anticline are covered by alluvium towards the east of Dheri Kila, and only appear again near Saidpur and Nurpur Shahan.

The anticline of Golra is hardly exposed to the west of the Mosque Dheri Shah Sikandar Wali. Some isolated exposures of variegated marls and a limestone ridge, that crosses the road from Rawalpindi to Shah Aladitta, mark its course. About 3 miles to the west of the oil-springs—between Sarai Kharabuza and Johd—the Upper Nummulitic is again well exposed as grey-black, fossiliferous, and variegated clays of a thickness of several hundred metres. Adjoining them towards the south appears the Nummulitic limestone, which crosses the road from Rawalpindi to Sang Jani as a ridge. The limestones break forth always more towards the west. They form the hills to the south of Sang Jani, accompanied on both sides by younger formations, and continue their course in the limestone hills of the Kala Chitta Reserve to the north of Kutbal. While the Golra anticline runs W.S.W., the southern border of the Margala Hills, to the north of Golra, runs directly west. Thus the sandstone-syncline between the two anticlines to the west widens out considerably, and reaches a breadth of about 4 miles in the neighbourhood of Sang Jani. Toward the east, on the contrary, this syncline of Sang Jani–Shah Aladitta becomes rapidly narrower. The sandstones forming the core of the syncline appear in the environs of Saidpur only in scanty patches embedded in the Upper Nummulitic, which, still farther east, at last as a narrow stripe, separates the limestones of the Golra anticline from the Hill-Nummulitic limestones of the principal anticline, both of which join to form one mountain mass to the east of Saidpur (see Plate I).

The occurrence of oil is therefore closely related to special geological features. It occurs only in the boundary region between the Hill-Nummulitic limestone and the Upper Nummulitic (Kuldana beds). It appears on the surface only where the beds have a normal position and a moderate inclination (below 60°). This is especially the case in places where the Nummulitic limestone dips axially under a closed cover of clays and marls of the Upper Nummulitic.

The oil-bearing bed is chiefly cavernous, marly limestone, and partly gypsiferous marls.

2. SAIDPUR–RATTA HOTAR.

Oil-springs.

The oil-spring of Ratta Hotar is situated $\frac{2}{3}$ mile north-west of the end of the Tonga Road from Rawalpindi to Nurpur Shahan, and a few hundred yards east of the park and the graves, where a Mohammedan priest resides. On the topographical map (1 inch = 1 mile) the place is marked by the name "Gugul pani". Along a little channel there are outcrops of a disturbed limestone mingled with oil-bearing marls 20–30 yards long and a few yards broad.

At the spring itself there is a hole from which water issues covered with thick oil. The oil flows drop by drop. The flow of the oil is said to be somewhat stronger in the dry season.

Geological Features.

The Section Ratta Hotar.—Section VI, Plate I, shows the geological situation of the oil-spring at Ratta Hotar.

The oil-bearing rock: the limestone lenses with interstratified clayey marls form the contact-layers between the compact Nummulitic limestones and the gypsiferous variegated clays of the "Upper Nummulitic". These lenticular limestones are also found elsewhere in the upper parts of the Nummulitic limestone. They are widely developed near Murree, and there also they are bituminous for long distances. I have found them again in typical development in the Eastern Salt Range between the Nummulitic limestones and the Murree sandstones, but there they were free from bitumen. A few metres south of the oil-springs the massive Nummulitic limestone is exposed, forming a steep ridge and dipping north at 70–80°.

To the north of the oil-rocks follow the typical variegated gypsiferous clays of the Upper Nummulitic. These dip north a little less steeply (about 65°).

To the east of the oil-springs sandstones appear between the oil-rock and the marls. They are also represented in Section VI, Plate I, although they are not visible at the oil-spring itself. I suppose these sandstones to form a synclinal core of Murree beds.

By the outcrops in Section VI of Rattar Hotar the existence of two anticlines with two corresponding synclines is proved.

The anticlinal cores consist of Nummulitic limestones, the

synclines of gypsiferous marls of the "Upper Nummulitic" and sandstones of the Murree beds.

The geological features of this section correspond to those of the Golra section. The southern anticline of Ratta Hotar is the direct eastern continuation of the oil anticline of Golra, as shown on the geological map (Plate I). The syncline between the two anticlines in Section VI is the continuation of the syncline of Sang Jani and Shah Aladitta. The Murree sandstones of this syncline, which north of Golra have a breadth of more than one mile, are reduced to a minimum at Ratta Hotar.

Environs of Saidpur.—The syncline with Upper Nummulitic clays north of the oil-springs of Ratta Hotar can be followed up to the west as far as Saidpur. It is always accompanied, on both sides, by limestones. To the west of Saidpur the variegated clays with gypsum appear in isolated complexes only, disposed in a way which leads us to suppose that overfolding of the northern anticlinal limestone core over the syncline has taken place. In the village of Saidpur, even at a place where oil is said to be found, nothing is to be seen of the variegated clays, which otherwise always accompany the oil; only limestone appears. The red clays are, however, visible immediately east of the village, and dip north at only 40°. It is probable that at Saidpur the clays are covered by overfolded limestones. North of the village we notice in the limestones planes of overthrust dipping north at 40°.

The bituminous rocks of Dhak Jiwan lie exactly in the line of the syncline Ratta Hotar–Saidpur. Thus it is most probable that this oil-bearing zone continues in depth below the limestone masses to the west of Saidpur.

Occurrence of the Oil.—Oil and oil-bearing rocks appear in the environs of Ratta Hotar especially in the transition beds between Nummulitic limestones and the younger gypsum-bearing clays of the "Upper Nummulitic". In some places oil-traces are said to occur also deeper in the Nummulitic limestones. As the rocks possess very differing qualities above and below the oil-zone, the oil-lines are easy to recognize. The limestone bed running from the village of Saidpur eastwards to Ratta Hotar and crossing, about 1 mile north of the village of Mandla, the side-valley of Bharakao contains the most important oil-shows on its boundary-lines on both sides towards the Upper Nummulitic. This limestone region is, indeed, the core of the anticline of Golra. Thus we find also in the Saidpur region the most important oil-spring, that of Ratta Hotar, on the north flank of the Golra anticline.

3. TRET-MURREE (Plate I, Sections VIII, IX).

The north-eastern continuation of the oil-zones of Golra and Saidpur–Ratta Hotar is well exposed on the high road from Rawalpindi to Murree, between Tret and Murree, and also on the

hill road from Murree to Kuldana and Khaira Gali. The observations made in this region I have entered on Plate I. The road from Rawalpindi to Murree runs from its entrance into the hills almost, exclusively in the sandstones of the Murree formation. Below Tret, however, where the road sharply curves to the north-west round the isolated hill, and where the footpath to Tret branches off, the road cuts red clays, then greyish-yellow lenticular or nodular marly limestones, and finally massive Nummulitic limestones, somewhat crushed. On the north side of the hill nodular marly limestones appear again and also the sandstone. Evidently we have to deal here with a tightly pressed anticline, in the core of which Hill-Nummulitic limestones appear. It is strange that the hanging layers dip, on both sides, steeply towards the anticlinal limestone core. The nodular marly limestone corresponds stratigraphically to the oil-rocks of Ratta Hotar, and indeed here,

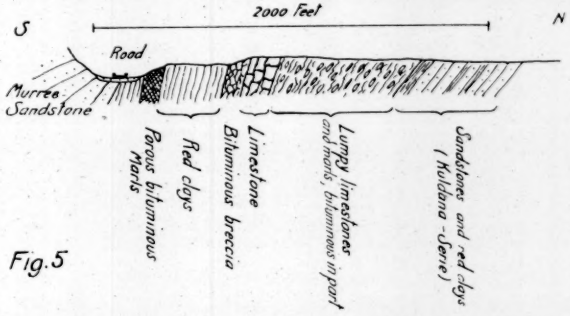


Fig. 5

too, it is bituminous, as can be seen from the exposures on the north side of the hill near the bungalow of Tret. I have followed up this anticline for many miles to the north-east as far as a little village, Khani Tak, in the steep forest ravine north of Murree (Plate I). There the limestones disappear among the sandstone masses, and the anticlinal core dives below the hanging beds. In the axis of the anticline the strata are standing almost perpendicular, more moderate inclinations occurring, however, in the south-east slope, e.g. near Charra Pani. The Murree sandstones in the south-east flank throughout show a moderate inclination (50°–20° south-east). The anticline is very rich in bituminous rocks from Tret onwards to its east end. These appear especially in the zone between Nummulitic limestones and the red gypsum marls of the Upper Nummulitic or, where this is missing, between limestone and Murree sandstones. They appear, however, also in the limestone mass itself or in limy-marly porous rocks of the Upper Nummulitic. They therefore seem stratigraphically equivalent to the oil occurrences at Golra and Saidpur.

The Upper Nummulitic can easily be examined, especially in the south flank of the anticline, the road to Murree cutting this formation

in nearly all its northern curves: at Ghora Gali, at Basra Gali, at Tschita Moor, at Sunny Bank, and where the road branches off to Kuldana. North of the Kuldana cross-road the road to Kuldana cuts the section Fig. 5.

The bituminous limestones are quarried and furnish good gravelling material. It is worthy of note that the massy Nummulitic limestones are less developed in this section, the nodular marly limestone, which forms the upper beds of the Nummulitic limestone series, predominating. This fact may, tectonically, be explained, in that the core of the anticline is sinking rapidly here, towards the east below and between the overlying Murree sandstones, as shown by the exposures near Khani Tak (Plate I).

The north flank of the anticline contains here also bituminous beds. Bituminous rocks are probably to be found along the whole length of the north flank, which is here less easily accessible than the south flank. I have examined this north flank in the deep gorge of the Kurang River. Sections VIII and IX of Plate I show the geological features stated there. The northern contact of the anticlinal limestones show throughout bituminous rocks. They are the same nodular limestones carrying bitumen as we have found at Kuldana. It is also the same bituminous zone struck by the Tret road. At the bottom of Kurang valley the bituminous rocks are accompanied by several sulphur springs; 7 or 8 miles to the north-east, at the end of the limestone range at Khani Tak, another sulphur spring comes forth, which also illustrates the geological conformity of the whole range from Tret to the east of Kuldana.

To the north of the section represented on p. 15 follow the sandstones of Kuldana, which I take to be a syncline between the anticlinal limestones. These sandstones are again followed, to the north, by thick red clays of the Upper Nummulitic, and then at Dara Gali, by a Nummulitic limestone anticline also containing bituminous beds.

This section has already been described by Wynne and later by Middlemiss.[1] His section stretches north as far as the Nummulitic limestone of Dara Gali. There seems to be a great probability of these northern Nummulitic limestone zones of Dara Gali being identical with the Golra anticline. The narrow anticline of Tret must then correspond to the pre-anticline of Mandla. From this fact we see the bituminous zones of Golra–Saidpur–Ratta Hotar extend very far towards the east, and it seems that most of the bitumen is found in those anticlines which are farthest advanced towards the sandstone foreland.

Some samples of the bituminous marls of Basra Gali and Ghora Gali gave 7–9 per cent bitumen (as benzol extract).

4. FATEHJANG.

A certain number of natural and artificial oil-shows are to be found some miles north-west of the little town of Fatehjang. Near the

[1] Memoirs Geol. Surv. India, vol. xxvi, p. 225.

village of Gundewali Bani (Gunda) there is a pit about 50 feet deep and a boring 75 feet deep, as well as several small shafts, from which oil is obtained occasionally.

Further details are to be found as follows :—

Wynne : "Note on the Petroleum Locality of Judkal, near Futtijung, west of Rawalpindi, etc." (Records Geol. Survey of India, vol. III, 1868, p. 73).

Lyman : *General Report on the Punjab Oil Lands* (Lahore, 1870).

The boring struck Nummulitic beds rich in fossils and cellular limestones.

About two miles west of Gunda, at the southern affluent of the Bhagwan Kas, oil-traces are to be found in gypsiferous green marls, and at the Bhagwan Kas itself we also find nice oil-outcrops in marly layers between limestones dipping steeply north.

Near the village of Charat there are also oil-outcrops as well as a boring 15 feet deep, out of which gas and oil escape. Oil-springs also appear in a little anticline west of Charat (about 1 mile).

The numerous oil-outcrops are also here restricted to the base of the Kuldana beds, which together with Nummulitic limestones rise in the shape of a steep anticline from under the Murree beds.

From the map and the sections I–II, Plate I, we see that we have here to deal with a complex anticline, the structure of which rapidly changes along the strike. The various cores of the subsidiary anticlines (consisting of marls and limestone) are separated from one another by distinct sandstone synclines; this can be seen very clearly at Gunda.

The whole complex of the Nummulitic limestones and the Kuldana beds near Fatehjang form an isolated anticlinal zone lying parallel to the front of the Chitta Pahar chief anticline, just as the anticline of Golra is related to the chief anticlinal zone of Margala.

Compared with the Golra region, that of Fatehjang shows on an average a less considerable dip of the strata, which is worth mentioning in regard to the oil occurrences.

The facies of the Kuldana beds (Upper Nummulitic) near Fatehjang is deviating from the development near Golra in so far as in the anticline of Fatehjang the clay—and marl—facies of the Kuldana beds extend into the underlying Nummulitic limestone as well as into the overlying Murree sandstone formation.

I wish to point out especially the considerable abundance of fossils in the clayey marls overlying immediately the Nummulitic limestones and the cellular dolomites. The exposures of these marls attract our attention by an enormous number of isolated individuals of *Assilina*. According to Zuber, *Assilina exponens* and *Nummulites perforatus* are especially abundant (loc. cit., p. 342).[1]

Near Charat I have found pieces of a big tooth in the "Upper Nummulitic" (Kuldana beds). Dr. H. Stehlin, of Basle, succeeded

[1] Wynne also mentions "teeth of sharks" and "large bones": Records, III, p. 73.

in reconstructing it. He was kind enough to tell me that we have to deal here with one of the two last premolars of a large Perissodactyle, which does not seem to belong to any of the genera known up to the present.

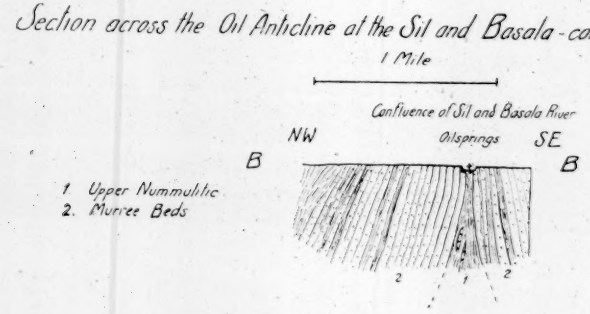


FIG. 6a.

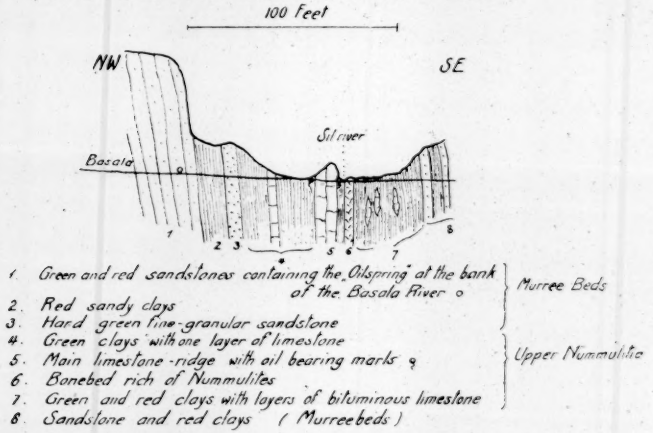

Special section across the oil bearing beds at the confluence of Sil River and Basala River near Murat
100 feet
NW
SE
Sil river
Basala
1
2 3
5 6
7
8
1. Green and red sandstones containing the Oilspring at the bank of the Basala River
2. Red sandy clays
3. Hard green fine-granular sandstone
4. Green clays with one layer of limestone
5. Main limestone-ridge with oil bearing marks
6. Bonebed rich of Nummulites
7. Green and red clays with layers of bituminous limestone
8. Sandstone and red clays (Murree beds)
Murree Beds
Upper Nummulitic

FIG. 6b.

5. SIL RIVER AND BASALA RIVER, NEAR MURAT.

The Oil-springs.—The place where the oil is found is at the confluence of the Sil and Basala, $1\frac{3}{4}$ miles east of Murat, which lies at the east end of the steep limestone range of the Kairi-Murat ridge. The distance from Rawalpindi is about 10 miles. Cart tracks lead over the flat country as far as 2 miles east of the oil-place, which is reached by a camel track crossing the steep canyon of the river, which is about 20 m. deep.

At the time of my visit (beginning of August) the river was rather high, and nothing could be seen of the oil-outflow. I was able, however, to determine the existence of calcareous marls richly impregnated with oil. I noticed them in the crevasses and flanks of the limestone ridge right in the Sil River.

B. S. Lyman [1] says of these oil-springs :—

" The oil rises up through the extremely shallow water of the river ; one drop at a time every minute or two gives rainbow colours to the surface of the river for the space of a few inches, then floats away and disappears. At a distance of about 20 yards north-easterly, apparently on the outcrop of the same bed of shales, is another like show of oil ; also at one or two other places between these extremes."

The oil-springs of the Sil and Basala Rivers are important on account of their geological situation. The rocks accompanying them are represented in Fig. 6*b*. These rocks are typical representatives of the " Upper Nummulitic ", which forms here a narrow zone (running N. 60° E.) between the sandstones of the Murree beds. The character of the oil formation is here entirely similar

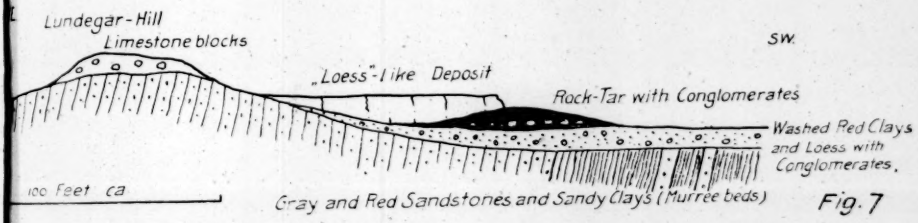


Fig. 7

to that of Golra and Saidpur. Bituminous limestones and marls are found along the strike of the beds on both sides of the oil-springs : to the west of the river in a steep channel in the plateau-margin about 30 m. above the river, to the east about 120 m. distant from the oil-springs. also in a narrow gorge in the steep slope.

Farther east on the plateau, the " Upper Nummulitic " can still be identified by the appearance of limestone lenticles (for the length of about half a mile). Farther on to the east only sandstones of the Murree beds are exposed.

Near the oil-springs, as shown by the sections, almost vertical bedding is found, and to the south and north there follow thick masses of also very steep Murree sandstone, which dip only a little less steeply north and south at a considerable distance from the springs, thus allowing us to recognize the anticlinal structure of the oilfield (Fig. 6*a*).

We can follow the anticlinal core to the east for not quite a mile in the sandstone ; farther east isoclinal stratification predominates,

[1] B. S. Lyman, *General Report on the Punjab Oil Lands*, Government Press, Lahore, 1870.

and alluvium covers the plain and prevents us from recognizing the structure of the Tertiary strata any farther.

On the plain to the west of the Basala River exposures are very rare. It is only at Murat, in the brook encircling the place, that the strata of the Upper Nummulitic are very nicely exposed. In the little valley, which branches off north from the eastern curve of the brook, outcrops of bituminous limestones occur.

To the west of the village the steep Nummulitic limestone masses of the Kairi-Murat ridge rise from the plain. The Upper Nummulitic and the Murree sandstones accompany the limestones at the foot of the mountains south and north of the ridge in steep or often overturned strata.

The village of Murat, therefore, lies at the very place where the massive Nummulitic limestones disappear to the east below the Upper Nummulitic beds.

Fig. 8

It is worthy of note that the bituminous character of the rocks is pronounced just at those places where the limestone anticline dives below. The axis of the anticline is, to the east, marked only by the Upper Nummulitic, while the massive limestones have definitely sunk below.

It is peculiar that the connecting link between the anticlinal core at Murat and the anticline at the oil-springs does not agree in its direction either with the general direction of the Kairi-Murdi ridge nor with the strike of the strata at the Sil and Basala Rivers. The anticlinal axis must, therefore, have suffered either a strong bend to the south between Murat and the Basala River or a displacement to the south along a tranverse fracture.

6. THE OCCURRENCE OF ROCK-TAR NEAR LUNDEGAR.

About 2½ miles south-west of Murat, near Dhak Bhatwari, a hill called Lundegar rises out of the gently north-west-rising surface of the country. The hill consists of limestone boulders, at the base of which sandstones of the Murree formation are exposed with steep dip (Fig. 7).

About 100 metres south-west from the hill a flat lenticular mass of tar appears from under a cover of loess, with an extension of about 15 metres. In a brook near by, the base of the tar-lens is denuded. It consists of mixed clays, loess, and conglomerates.

Here and there steep sandstones and clays of the Murree beds are exposed below them.

About 200 metres farther west the steep Murree beds are again visibly covered by boulders and loess. At the base of the alluvial deposits bitumen appears. Also the strata of the Murree beds are in some parts impregnated with it (*vide* Fig. 8).

No doubt the tar is lying in a secondary position, and in all probability originates in the Upper Nummulitic that is exposed at the foot of the limestone ridge of Kairi-Murat (comp. Section X, Plate I).

The tar occurrence of Lundegar is a further proof of the great extension of oil and bitumen in the Upper Nummulitic.

(*To be continued.*)

The Interglacial Problem and the Glacial and Post-glacial Sequence in Northumberland and Durham.

By David Woolacott, D.Sc., F.G.S.

SINCE my papers on "The Superficial Deposits and Preglacial Valleys of the Northumberland and Durham Coalfield" [1] and "The Origin and Influence of the chief Physical Features of Northumberland and Durham" [2] were published, a great deal of detailed work has been done on the glacial phenomena in the two north-eastern counties by Smythe,[3] Merrick,[4] Herdman,[5] Trechmann,[6] and myself.[7] As I have given much attention to this subject it may be of interest and value if I give a brief resumé of my views, a general summary of the work done, and attempt to show the general sequence of the phenomena that have been described. My extensive study of the Drift in these two countries and elsewhere has convinced me of its complexity. I cannot, therefore, be dogmatic on any points, but will endeavour to show the general trend of my thoughts on the subject.

The complexity of the superficial deposits is evident to all who have studied a typical glaciated area in detail, and the widely

[1] Quart. Journ. Geol. Soc., vol. lxi, 1905, p. 68.

[2] Geogr. Journ., July, 1907, p. 37.

[3] "Glacial Phenomena of the country between the Tyne and the Wansbeck": Trans. Nat. Hist. Soc. Northumberland, etc., 1914. "Glacial Geology of Northumberland": ibid., 1908.

[4] "Glacial Deposits around Newcastle-upon-Tyne": Proc. Univ. Durham Phil. Soc., 1909.

[5] "Glacial Phenomena of the Vale of Derwent": ibid., 1909.

[6] "The Scandinavian Drift of the Durham Coast": Quart. Journ. Geol. Soc., vol. lxxi, 1915, pp. 53–82. "On a Deposit of Interglacial Loess and some transported Freshwater Clays on the Durham Coast": Quart. Journ. Geol. Soc., vol. lxxv, pt. iii, 1920, pp. 173–203.

[7] "The Preglacial Wash": Proc. Univ. Durham Phil. Soc., 1906. "Borings at Derwenthaugh and Durston": ibid., 1909. "Geology of N.E. Durham and S.E. Northumberland": Geol. Assoc., 1912, etc. There is also a large amount of carefully recorded data in the Boulders Com. Reports of the Univ. Durham Phil. Soc., 1905–12.

diverse views that are still held regarding their origin are an evidence of the difficulty experienced in the interpretation of the phenomena. Accepting as definitely proved that the greater part of the Drift is the product of an ice-sheet, the main controversy now centres round whether there were true Interglacial episodes in the formation of the Glacial deposits; some geologists asserting that the evidence proves there was a succession of Glacial epochs in the Pleistocene Period [1] and some that our era may even be an Interglacial one, while others affirm that there is no evidence of any such intervals in the Glacial deposits of Britain.[2] As I propose to discuss the evidence that has been advanced recently in favour of Interglacial periods in the Drift of the north-east of England [3] it may be well to consider what is meant by such periods, and the nature of the evidence that seems to be necessary to prove that they occurred. The subject is specially complicated because of the difficulty of distinguishing in a limited area an interval of ice-retreat from an Interglacial period, also because there are no exact criteria by means of which Interglacial deposits can be differentiated from interval-deposits or even sometimes from fluvio-glacial beds. If an area has once been glaciated and the ice has retreated, it is obvious it may be reglaciated without a true Interglacial period intervening, for by such an epoch we imply not only the retreat of the ice from a limited area and its subsequent return, but the disappearance or almost total disappearance of the ice from the main gathering grounds (produced by the oncoming of a warmer climate over the whole glaciated region) and then the regrowth of the ice-sheet and the reglaciation of the area considered. Within the limits of the country studied it might be difficult to distinguish a temporary retreat of the ice from an Interglacial period, as they might be marked by the same phenomena, although to a less extent and over a smaller area in the one case than the other. Interglacial periods might be signalized on a marine area by the production of a shore-line and the laying down of deposits, on a land area by the formation of lakes and lake deposits, plant beds, loess deposits, and by a considerable amount of denudation; and somewhat the same phenomena, although on a lesser scale, might mark in a limited area a retreat of the ice from it alone. The only way in which an Interglacial epoch can be proved is by showing that the retreat of the ice took place over the whole glaciated region at the same time. It might obviously be impossible to distinguish in one area the phenomena of an interval of ice-retreat from those of a true Interglacial period; thus the difficulty that has arisen in connexion with the Interglacial problem is due in the first place to the non-recognition of the fact

[1] J. Geikie, *The Great Ice Age*. And other authors.

[2] Lamplugh, Address to the Geological Section, British Association, York, 1906, etc. It has also been asserted recently by a Swiss geologist that there is no evidence of true Interglacial periods in the Glacial deposits of Switzerland.

[3] Trechmann, op. jam cit., Quart. Journ. Geol. Soc., 1920.

that ice-retreat does not necessarily imply an Interglacial period, and in the second place that sweeping generalizations have been made before the phenomena in different areas, due to the intervals of ice-retreat, have been correlated. If, however, this question is to be finally solved it will only be by the working out of deposits, etc., due to the episodes of ice-retreat in each area and their careful correlation, that it will be found if such intervals are so widespread as to be really Interglacial in character.

I would therefore suggest that until this problem has been more fully investigated the term "Interval-in-the-Glaciation" of an area be used when only a limited extent of ground is being studied and not Interglacial period to designate epochs of ice-retreat, and that the term "Interval-deposit" be applied to beds formed during such periods, until by an accumulation of evidence they are proved to be really Interglacial in character. This would tend to define the problem clearly, and to do away with the assumption that any deposits which are not of direct glacial formation in the Drift are Interglacial. The chief difficulty in the acceptance of a series of Interglacial periods is found in the fact that it is difficult to correlate the phenomena that have been taken to mark such episodes in different areas; indeed, it has appeared to some geologists that a change in the foci of ice accumulation and consequent direction of maximum movement might explain most of the phenomena, rather than a succession of Interglacial epochs. If the term "Glaciation-interval" was adopted, and the effects produced in such intervals were gradually worked out as regards their relative importance and extent, and afterwards, if possible, correlated in different districts and later in different countries, it would ultimately be possible to find out whether any intervals were of such extent and importance as to constitute true Interglacial periods. Time alone is not the factor, as an "Interval-in-the-Glaciation" might be as prolonged as an Interglacial period, but it might, however, only be of short duration. No "Interval-deposit" or "Interval-denudation" should be accepted as Interglacial until it is definitely proved to be so. Only in some such way will a really sound general idea of the Glacial deposits be obtained, and it be settled whether they are the result of one continuous glaciation, or of a succession of Glacial epochs.

The subject is further complicated by the difficulty of distinguishing true Glacial from Interglacial deposits, and both of these from beds laid down during an Interval-in-the-Glaciation. Some geologists have regarded the thick sands and gravels occurring in the boulder-clay of the North of England as Interglacial, but some of them may not even be Interval-deposits. They may only be of fluvio-glacial origin, and have been formed during periods of periodic and seasonal ice-melting. There are, however, some beds which may be Interval- or even Interglacial deposits, and their inclusion as such may bear no relation to their

thickness or extent; e.g., the local deposit of sands and gravels at Horsebridge Head, north of the mouth of the Wansbeck,[1] resting on the bed-rock beneath typical boulder-clay, which has been described by one writer as a Preglacial shore-line and by another as the deposit of an early Glacial stream, may have been deposited during an Interval-in-the-Glaciation of Eastern Northumberland or may even be Interglacial; while, on the other hand, the bed of loess at Warren House Gill lately described by Trechmann as an Interglacial deposit [2] may not be such, but may be an Interval-deposit marking an important episode in the glaciation of East Durham between the deposition of the Scandinavian and British drifts. (No deposits of peat, plant beds, etc., with a temperate flora are yet known in the Glacial deposits of Northumberland and Durham, and so need not be discussed in this paper.)

There is another point to which the greatest attention should be paid if the Interglacial problem has ever to be solved, and that is the exact use of the terms Pre-, Inter-, and Postglacial. A bed beneath boulder-clay is not necessarily Preglacial, as e.g. the deposit at Horsebridge Head or the Sewerby raised beach at Bridlington (both of which have been considered to be Preglacial; the only thing certain is, however, that they were formed prior to the Glacial deposit under which they lie). In the same way a bed occurring in the boulder-clay which was not formed or not directly formed by ice is not necessarily Interglacial, and beds resting on typical boulder-clay with only recent deposits above are not always Postglacial.

The difficulties met with in the working out of the sequence in the Drift of an area are due to several causes, the principal of which are (*a*) the irregular surface on which it rests, (*b*) the possibility of the moraine profonde of one ice-stream being overlain by that of another from a different region during one continuous period of glaciation, (*c*) the possibility of the moraine profonde, etc., of one ice-stream being entirely removed by another ice-flow without an Interglacial period or even a "Glaciation-interval" between, (*d*) the possibility of some of the deposits being laid down by water without even an "Interval-in-the-Glaciation", and (*e*) (as a result of these) the complex manner in which the beds change from point to point so that it is exceedingly difficult to correlate them. Every worker in the field on the Drift must have been impressed by the complexity of the deposits, the detailed and exact observation that is necessary to determine the mode of origin of certain beds, or to work out the sequence of events, and by the great need there is for the exact use of terms in describing the formations.

There are certain features of the Glacial and Postglacial phenomena of the two north-eastern counties on which most glaciologists would

[1] A fuller description of this bed is given later.
[2] Op. jam cit., 1920, p. 187.

agree. I propose briefly to summarize these, and subsequently to discuss more controversial and indefinite subjects. The most important of the former are :—

(1) In Preglacial times—probably starting with the Miocene—the surface of Northumberland and Durham was eroded by a series of easterly-flowing streams, which were not adjusted to the present coastline.[1] The maximum proved depth of the Preglacial valleys beneath sea-level is 169 feet, occurring at Dunston, west of Gateshead, near the junction of the " Wash " [2] and the " Tyne ".[3] These mature watercourses probably were considerably and unevenly deepened by glaciation. Those which lay in the same direction as that of the ice-movement had a series of rock basins developed in them. In my paper on the superficial deposits I prove that the slope of the bed-rock of the " Tyne " is of a switchback nature,[4] a feature probably due to the scooping out of the softer beds by the Tyne glacier.[5] In valleys such as the " Wash ", which lay across the direction of the ice-flow, the slope of the Preglacial Thalweg is, however, continuously in one direction.[6] The depth of the " Tyne " at its mouth is not so great as it is further inland nor as that of the " Wash ", and I am of the opinion that this is in part due to the uplift that produced the Postglacial raised beaches having been more accentuated in the coastal region. It would appear certain that at some time prior to the Glacial period the country was more elevated and that the constructional shore-line lay far to the east and north of the present one,[7] but there is no evidence in the two north-eastern counties as to the position of the coastline immediately prior to the oncoming of the Scandinavian ice-sheet.[8]

(2) Before this great outflow, Teglian, Cromerian, and other deposits were laid down on the North Sea area, and some of these were pushed forward by the advancing ice.[9]

(3) The first ice to reach the east of Durham was that from

[1] Geogr. Journ., July, 1907.

[2] In this paper all Preglacial valleys are denoted by inverted commas.

[3] " Note on Borings at Derwenthaugh and Dunston ": Proc. Univ. Durham Phil. Soc., 1909.

[4] Quart. Journ. Geol. Soc., vol. lxi, 1905, p. 76.

[5] Merrick, who has studied the Tyne valley very minutely, has also come to the conclusion that rock-basins were developed along it.

[6] " The Preglacial Wash ": Proc. Univ. Durham Phil. Soc., vol. ii, 1906, p. 5.

[7] Geogr. Journ., July, 1907, p. 37.

[8] The buried Chalk cliff and associated deposits at Sewerby, near Flamborough Head, is a little above sea-level. Lamplugh states " that they prove that at the beginning of glacial times the North Sea held possession of its basin, and with a surprisingly slight difference from the present level". I have always doubted that the level at the beginning of Glacial times was the same as the present. I consider it to have been more elevated. It is not certain that the Sewerby raised beach is not an Interval-deposit. (Or, as suggested by Trechmann, op. jam cit., p. 190, an Interglacial one.)

[9] Trechmann, Quart. Journ. Geol. Soc., vol. lxxv, pt. iii, 1920, p. 193.

Norway[1]—the Scandinavian Drift being a "pure culture" of Norwegian rocks, together with such material as it obtained in its passage across the North Sea.[2]

(4) The course of events after the first oncoming of this ice-sheet is difficult to decipher (as the reading of it depends on whether Interglacial periods are accepted or not, and also on the manner in which it is thought certain beds, etc., were produced),[3] but of the final period of glaciation we can form a fairly clear picture. During this epoch the coastal area of Northumberland and Durham was invaded by ice from several regions. There were four main ice-streams[4] from the west, all of which received a southerly trend along this area due to the pressure of the invading sheet from the Continent. These four western flows were (*a*) one down the Firth of Forth (Forth ice),[5] (*b*) one down the Tweed which swept round the Cheviots (Tweed–Cheviot ice), (*c*) a broad stream from the south-west of Scotland and the Lake District which came over the Northumberland moors, was confluent with a small Alpine glacier down the South Tyne valley, and filled up the Tyne valley (Lake District ice, south-west of Scotland ice, Northumberland ice or Tyne valley ice) and (*d*) one from the Lake District over Stainmoor, bringing with it the Shap boulders and confluent between Cotherstone and Middleton[6] with a glacier down the Tees valley (Lake District (Shap) ice,[7] Stainmoor ice or Tees valley ice). The indicator boulders and the direction of the glacial striations prove that these main flows, following the general contour of the country, moved eastwards in more or less parallel lines until they came under the influence of the Scandinavian ice-sheet,[8] which diverted them

[1] Professor Bonney (Presidential Address, Brit. Assoc., Sheffield, 1910, p. 23) has endeavoured to show that the Norwegian deep off the south-west coast of Norway would offer a difficulty to the passage of an ice-sheet, but I am in agreement with Dr. Trechmann when he states that this deep need not be considered as presenting a difficulty, and I also consider that the evidence (distribution of boulders, marine shell-bearing gravels and sands pushed inland, etc.) proves that the Scandinavian ice did actually move over the North Sea area, and that a lobe impinged on the Durham coast near Castle Eden.

[2] Trechmann, op. jam cit., p. 186.

[3] e.g. the deposit at Horsebridge Head.

[4] Minor glaciers in the Cheviots and Pennines are not considered here, e.g. a glacier came down the Wear valley and was confluent with the Northumberland ice on the north and Lake District (Shap) ice on the south.

[5] Boulders of olivine-basalt, most probably from the Firth of Forth, occur in the clay at Fulwell Quarries and of St. Abb's porphyrite in that near Tynemouth.

[6] Three miles and 8 miles west of Barnard Castle respectively.

[7] It appears highly probable that boulders of Shap granite do occur in the Drift of the Tyne valley. The evidence for their occurrence is very strong.

[8] Along the coast of Northumberland from Bamborough to the Wansbeck there are two boulder clays of different origin, a lower typical bluish clay mainly of western derivation and an upper reddish clay of Tweed valley and northern origin. Smythe, *Glacial Geology of Northumberland*, p. 94. In a depression at Hartlepool there is a boulder clay with only Western erratics (Trechmann, op. jam cit., 1920, p. 191), and at Horsebridge Head there is a deposit containing Scottish rocks beneath the Western derived boulder clay.

towards the south, so that they formed a Piedmont glacier. This composite ice-flow moved parallel to the coast of Northumberland and Durham.[1] They also prove that this was the direction of the ice-streams before they began to retreat from North-East England. Along the coastal border of Northumberland and Durham all the observed directions of the striations have this southerly trend. In Northumberland on the open west country they are from west to east, but along a coastal belt about 12 to 14 miles wide there is a distinct series all directed southwards. In one or two places a few miles inland, as at Burradon and South Charlton, there are two sets of striations, an earlier easterly and a later southerly.[2] In Durham, owing to the more irregular contour of the eastern area, this belt is not so distinctly marked or has not yet been so clearly worked out, but the same orientation is clearly observable along the entire coastal region into North Yorkshire.

STRIATIONS ALONG THE COASTAL BORDER OF NORTH-EAST ENGLAND.*

Farne Islands	S.S.E.
Budle Bay	S.E. and S.S.E.
Swinhoe†	S.W.
Chathill	S.S.E.
Newton Sea Houses	S. 35° E. and S.
South Charlton (two striations)	earlier E. later S.
Little Mill Quarries (two striations)	earlier S. 17° E. later S.S.W.
Near mouth of Coquet	S.
Horsebridge Head (mouth of Wansbeck)	S.
Burradon (three striations)	earliest 56° N. of E. 20° S. of E. latest 44° S. of E.
Kenton Quarries (near Newcastle)	S.E.
The Flatts, North Shields	S.S.E.
Roker, Sunderland‡	W.S.W.
Fulwell Quarries	S.
Salterfen Rocks (2 miles S. of Sunderland)	S. 17° E.
Haswell Quarry	S.
Wingate	S. 10° E.
Eaglescliffe	W.S.W., S.W., and S.W. by W.
Hob Hill, Saltburn	S.E.

* From records by Smythe, Trechmann, Kendall, Tate, Barrow, and myself.

† From an old unconfirmed record by Tate.

‡ Observed by Professor Kendall. It is more westerly than the rest of the striations round Sunderland, but the rock fragments found in the Grindon Kaim suggest that the ice was moving in this direction at one period in this area, e.g. fragments of Concretionary Magnesian Limestone occur in it west of the outcrop of that rock.

At the end of this period of maximum glaciation in North-East England the combined Forth and Tweed–Cheviot ice was moving due south along the coastal border, the ice from the Lake District

[1] Smythe, op. jam cit., pp. 89–90.

[2] We as yet know nothing about either the Indicator boulders or the direction of the striæ in the floor of the Preglacial "Sleekburn", "Tyne", or "Tees".

and South-West Scotland streaming across Western Northumberland was pressed south-eastwards over North Durham, and the Tees valley ice was diverted southwards. The northern ice that moved down the coastal region of South-East Northumberland and East Durham thus brought with it to these regions Scotch, Cheviot, Lake District, and Northumberland boulders, and to the Cleveland area all these together with Scandinavian rocks.

(5) During the same epoch this coastal ice carried with it in its passage southwards shore and other deposits. These were pushed inland, and being reassorted by glacial streams were deposited in mounds [1] along the margin of the melting ice-sheet, the Grindon, Warden Law, and Sheraton Kaims of East Durham being formed.

In his work on the glacier-lakes of Northumberland, Dr. Smythe has proved that the western ice from South-West Scotland and the Lake District was the first to retreat in this county,[2] and the evidence corroborates this in North-East Durham, as the Grindon and Warden Law [3] Kaims to the west of Sunderland [4] were formed on the free margin of the Tweed–Cheviot ice. Near Warden Law, cutting across the Permian escarpment, is a dry channel which may have been formed by the waters from the glacial streams that deposited this Kaim and the associated sands and gravels The country lying on the western boundary of this ice-sheet was free from ice in this region at that time. In the south of the county the shell-bearing Kaims at Sheraton were similarly formed on the free margin of the same ice-sheet,[5] and the shell-bearing spreads of cemented sand and gravel in South-East Durham are also fluvio-glacial deposits formed under similar conditions.[6]

(6) During the period of the maximum pressure of the combined ice-flows along the coastal region of North-East England the glacier-lakes of Cleveland were formed, the phenomena associated with which have been so fully described by Professor Kendall.[7] These lakes lasted until the beginning of the retreat of the ice from the coastal region.

(7) About the same time a system of ice-dammed lakes existed in

[1] Adopting the classification of fluvio-glacial mounds and ridges into Kaims, Eskers, and Osars proposed by Professor Gregory in a paper read before the Royal Society on April 29, 1920 (Geol. Mag., June, 1920), those of Northumberland and Durham are all Kaims. They were formed along the margin of the ice-sheet, some being deposited in glacier-lakes and others not.

[2] "Glacial Geology of Northumberland": op. jam cit., p. 104.

[3] Warden Law is 5 miles inland and 646 feet above sea-level. The gravels are 200 feet thick. Grindon is about the same distance inland.

[4] "Geology of N.E. Durham and S.E. Northumberland": op. jam cit, p. 102.

[5] A list of shell-fragments collected in these Kaims by Trechmann is given in the Quart. Journ. Geol. Soc., vol. lxxv, pt. iii, 1920, p. 194. They are 4 miles inland, and about 400 feet high.

[6] I have collected shell-fragments from the gravels at Dalton Piercy, near Hartlepool.

[7] Quart. Journ. Geol. Soc., vol. lviii, 1902, pp. 471–571.

the Cheviots,[1] and in the tributary valleys of the Tyne and Tees.[2] The overflow channels connected with the latter are one of the most marked physiographical features of South-West Northumberland and Western Durham. The glacier-lake of the Derwent valley [3] was formed when the Lake District–Northumberland ice was feeling the pressure of the coastal ice many miles inland.

(8) The phenomena connected with the period of ice-retreat are specially well-marked in Northumberland, and have been very carefully worked out by Smythe.[4] He has proved that the first ice to retreat in that country was the western flow from South-West Scotland and the Lake District, while the Tweed–Cheviot ice still occupied the coastal border.[5] A system of temporary lakes was formed ; the numerous overflow channels from these and the Kaims deposited by streams flowing into them from the free margin of the ice-sheets are among the most distinctive features of the physical geography of Mid-Northumberland. About the same time the gap at Ferryhill was cut by a stream flowing from waters held up by ice in the Tees valley,[6] and the gorge of the Wear near its mouth was probably started by an overflow stream when the Tweed–Cheviot ice was holding up temporary waters to the west and finally retreating from North-East Durham. Further to the west the phenomena connected with the retreat of the ice are also in places clearly observable. Beyond the limits of Western Northumberland the retreating ice held up waters of some magnitude, the overflow channel from which is the great swire of the Tyne Gap.[7] The retreat of the Lake District (Shap) ice across Stainmoor is distinctly marked on Cotherstone Moor by the well-developed group of Kaims known as the Burners Hills. The contrast between these conical fluvio-glacial mounds and the flat-topped table-like Millstone Grit hills—butte- or mesa-like remnants of a small dissected plateau—of Goldsborough and Shacklesborough on either side of them forms one of the distinct features of the country lying between Barnard Castle, Bowes, and Middleton-in-Teesdale.

(9) While the position of many valleys now dry or still drainage channels was determined by the overflow channels from glacier-

[1] Kendall & Muff, Trans. Edin. Geol. Soc., vol. viii, 1902, pp. 226–30 ; Woolacott, Geogr. Journ., July, 1907 ; Smythe, *Glacial Geology of Northumberland*, 1912.

[2] Dwerryhouse, " Glaciation of Teesdale," etc. : Quart. Journ. Geol. Soc., vol. lviii, 1902, pp. 572–608.

[3] Herdman, " Glacial Phenomena of the Vale of Derwent " : Proc. Univ. Durham Phil. Soc., vol. iii, pt. iii, 1909.

[4] *Glacial Geology of Northumberland*, 1912.

[5] Ibid., p. 104

[6] Woolacott, Geogr. Journ., 1907, p. 43, and Trechmann, op. jam cit., Quart. Journ. Geol. Soc., 1920, p. 192.

[7] Smythe, *Glacial Geology of Northumberland*, p. 106. The course of this valley was probably first of all determined in Preglacial times by the Irthing, which appears to have been then a tributary of the South Tyne. Woolacott, Geogr. Journ., July, 1909, p. 8.

lakes or by streams flowing from the margins of the ice-sheets, yet when the ice had finally left the country it was the relative contour of the surface of the bed-rock and drift that was the determining factor in valley development. The valleys of the Tyne and Tees and Upper Wear were superimposed on the partly filled Preglacial channels, but many of the smaller of these had been entirely obliterated, and the direction of the Postglacial streams bear no relation to them. When the direction of ice-flow had been across the pre-existing valley, there was left after the ice had vanished a thicker deposit of Drift on the lee-side of the valley than on the other. This contour of the glacial deposits forced the new streams to erode their courses on the comparatively driftless side of the valley. The most-marked channel thus produced is that of the Wear from Durham past Finchale Abbey towards Chester-le-Street,[1] which is here developed in rock and boulder-clay on the eastern side of the "Wash". The Wear valley thus is a composite one, being a combination of three types—in its higher reaches it is superimposed on the pre-existing channel, from near Durham to Chester-le-Street its course was determined by the Drift-contour, but the gorge near its mouth was originally eroded by an overflow stream from ice-dammed waters, and was finally developed since the uplift of the Durham coast in late Glacial or Postglacial times.

(10) The dry valleys of Northumberland and Durham which form such a distinct feature in its physiography have been produced in three distinct ways, viz.: (*a*) some are Preglacial channels which have not been filled up by drift, (*b*) some are the forsaken overflows from glacier-lakes, (*c*) some were formed by streams that flowed from the margin of the ice-sheet—on to country which was not occupied by lakes—and are thus associated with Kaims.

(*a*) The dry valleys of the Permian area round Sunderland, of which Tunstall Hope is a typical example, are mature, comparatively driftless valleys, whose outlets were blocked by material deposited by the Tweed–Cheviot ice as it moved along the coastal region and by the marginal deposits of the sea as the raised beaches were being formed. (*b*) The valleys which were eroded by the overflow waters from temporary lakes held up by ice are singular in form and position and bear no relation to the present drainage or to any possible river drainage of the past.[2] They are usually trench-

[1] There are several of this type in Northumberland. Smythe, op. jam cit., p. 112.

[2] Professor Bonney, discussing the glacier-lakes of Cleveland (Pres. Address, B. A. Sheffield, 1910, p. 29) has suggested that "the so-called overflow channels much more closely resemble the remnants of ancient valley-systems . . . and they suggest that the main features of this picturesque upland were developed before rather than after the beginning of the Glacial Epoch", but a detailed examination of most of the more important dry channels of Northumberland, Durham, and Cleveland has convinced me that—with certain exceptions, as for example some on the Permian area of East Durham—it is impossible for the great majority of them to be the remnants of old drainage systems.

like in character with flat bottoms and have obviously been cut quickly under peculiar conditions. They breach watersheds, sever spurs, and trench hill-sides. Some of them cut through the drift into the bedrock, thus affording evidence of their origin in late Glacial times. Dr. Smythe has mapped about seventy in Northumberland, and in Durham there are many well-developed gorge-like examples. Owing to the Nunatakkr of the Crossfell ridge preventing the western ice from sweeping over South-West Northumberland and the west of Durham, this country was not glaciated to the same extent nor in the same way as the main part of Northumberland. (The Cheviot massif had its own local glaciers and its borders were swept by the Tweed ice on the north and the western ice on the south, and is therefore also a distinct area.) The glaciers in this protected region of West Durham and South-West Northumberland were valley-glaciers, Alpine in type, and on its northern and southern borders the glacier-lakes in the tributary valleys of the Tyne and Tees were formed on high ground, and the swires thus cut across high watersheds and are sometimes most striking in their appearance and position. In Mid-Northumberland the phenomena due to the retreat of the ice can, be very clearly studied. Dr. Smythe has shown that the line of junction between the Tweed–Cheviot coastal ice and the Western ice was a position of cleavage and weakness, and that temporary waters were held up on the ice-free country between these sheets as the ice-streams decreased, the overflow valleys and the fluvio-glacial Kaims being exceptionally well developed.

(*b*) The glacier-lake phenomena connected with the Tees ice is specially interesting near Middleton. The tributary valleys of the Eggleshope Beck and the Blackton Burn had lakes formed in them, and here both direct overflow channels across the watershed between the Tees and Wear and a severed spur between the two minor valleys are clearly marked. Cutting across the ridge of Knotts Allotment beneath the Millstone Rigg, between the Eggleshope and Blackton Burns, are a well-defined series of flat-bottomed nicks, one below the other—notches in the spur developed by overflow marginal streams as the Tees glacier diminished in volume. This remarkable severed spur forms one of the most distinct features of the landscape between Barnard Castle and Middleton. It is perhaps worthy of note that some of these slacks afford a means of roughly determining the thickness of the ice in the main valley when they were formed; thus the trenches on this spur lie between the 1400 and 1500 contour, while the height of the base of the Tees valley at this point is from 600 to 700 feet. As the highest notch was cut at the time of the maximum thickness of the Tees valley ice, the glacier occupying this valley between Middleton and Romaldkirk must have been 700 or 800 feet thick.[1]

[1] The Tees valley glacier was probably held up for a time in this region by the Lake District (Shap) ice sweeping over Stainmoor.

(*c*) Some swires, and also valleys which are now permanent watercourses (to which, however, the streams in them are often obviously not adjusted) were directly formed by streams flowing from the ice-margin, whose load of sediment was deposited as a Kaim. The Burners Hills, already noticed as occurring on the Cotherstone Moor, have drainage channels connected with them, and the trench now occupied by the How Beck is the course of the escaping glacial waters. Dr. Smythe has also noticed the association of Kaims with dry valleys in Northumberland.[1] The glacier-streams in such cases did not flow directly into lakes, and hence sometimes developed wide and deep trench-like slacks.

(11) One of the most striking features of the superficial deposits of these two counties is the great amount of erosion and reassortment of glacial material that has taken place along the main valleys of the Tyne, a feature which was first clearly pointed out by Lebour.[2] The river terraces formed from the Drift in this valley between Bardon Mill and Haydon Bridge by the Glacial and Postglacial streams can be traced as high as the 300 feet contour-line. This is in distinct contrast with the apparently small denudation of the kaims, drumlins, and other surface features of the Drift out of the line of the main valleys, but this may be deceptive as these mounds and ridges may be much reduced in size, although their original contour is still preserved.

(*To be continued.*)

The World's Copper Production.

By F. H. Hatch, Ph.D., M.Inst.C.E., Past-President of the Institution of Mining and Metallurgy.

THE following article originally appeared in the *Times* Trade Supplement of August 28 last. It is here reprinted with some small additions by the courtesy of the proprietors of that Journal.

The world's consumption of copper at the beginning of the nineteenth century was some 15,000 tons[3] per annum. By the end of the century it had increased to over 600,000 tons per annum, and it reached a million tons by the year 1912. In 1917 it was close on one and a half million tons.

This era was one of continually growing engineering activity, and the high consumption of copper in the latter part of the period was chiefly due to the great demand for that metal for purposes of electric power generation and transmission, while during the late

[1] *Glacial Geology of Northumberland*, p. 102.

[2] *Geology of Northumberland and Durham*, p. 15, and "Certain Surface Features of the Glacial Deposits of the Tyne Valley": Nat. Hist. Trans. Northumberland, etc., vol. xi, pt. iii, 1893.

[3] Metric tons throughout.

War a considerable use was made of the metal and its alloys in the manufacture of war material.

Such remarkable increases in consumption demanded fresh sources of supply, which did not fail to be discovered. During the nineteenth century new deposits of copper ore were developed, at first in South America and in Cuba, and, later on in the century, in the United States, Australia, South Africa, and Canada. Another source of supply from the sixties onward was the copper smelted at British ports from the cupriferous pyrites imported in vast quantities from Spain and Portugal for its sulphur content.

In the following table will be found the world's production of copper for every fifth year from 1803 to 1918.[1]

TABLE I.

World's Production of Copper for every Fifth Year.

Year.	Metric Tons.	Year.	Metric Tons.
1803	15,000	1863	96,000
1808	16,000	1868	110,000
1813	17,000	1873	122,000
1818	19,000	1878	154,000
1823	23,000	1883	199,000
1828	27,000	1888	262,285
1833	31,000	1893	310,704
1838	36,000	1898	441,868
1843	42,000	1903	609,985
1848	52,000	1908	790,238
1853	63,000	1913	1,002,300
1858	78,000	1918	1,395,160

At the beginning of the nineteenth century the world's copper consumption of some 15,000 tons per annum was easily covered by the production of the United Kingdom, Russia, (Bogoslovsk), Japan, Chile, Sweden (Falun), Norway (Röros), and Germany (Mansfeld), together with small amounts from other countries. This order is that of the importance of the contribution. The chief producer—the United Kingdom—furnished nearly a half of the whole world's production from mines in Cornwall, Devonshire, Anglesey, and Ireland.

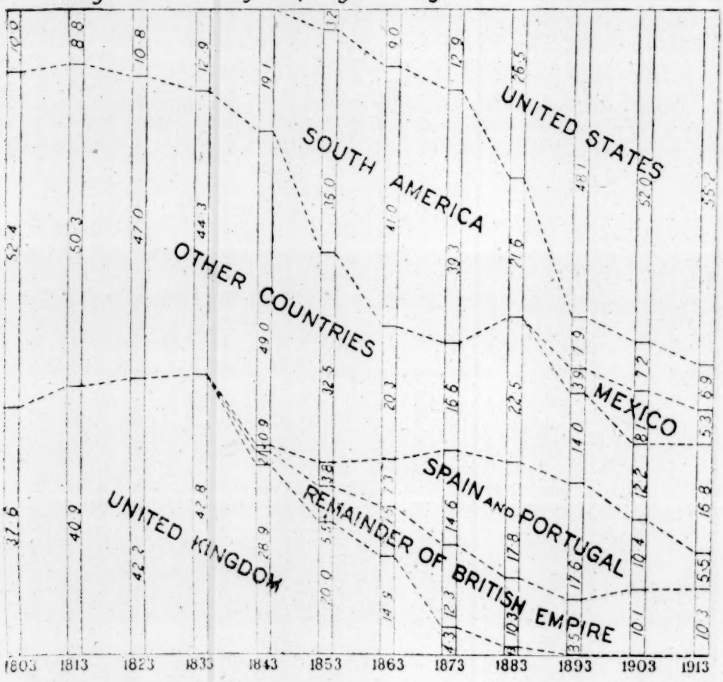
The introduction of copper sheathing for wooden ships was responsible for a gradual but not rapid increase in consumption until the forties, when it reached close on 40,000 tons per annum. The United Kingdom was still the largest producer (accounting for a third of the whole), followed by Chile, Russia, and Japan.

[1] The figures for 1803 to 1883 have been estimated from the world's decennial production given in Messrs. Nicol Brown & Turnbull's *A Century of Copper*. Subsequent figures up to the year 1908 are from the Chief Inspector of Mines' Report, part iv. The figure for the year 1913 is from Merton's Tables, and that for 1918 from the *Engineering and Mining Journal*.

The expansion of the engineering trades then caused a more rapid increase of consumption, and by the middle of the century it reached close on 60,000 tons per annum. British Colonies (Australia and the Cape) and the United States now began to take part in production, but the United Kingdom maintained its lead, furnishing a quarter of the whole. The countries next in importance were Chile, Cuba, Russia, and Japan. The Chilean output was from rich oxide ores, which were imported into the United Kingdom for smelting in Swansea. Large quantities of similar ores were brought

COPPER FROM HOME ORES.

Diagram of Percentage Output by Producing Countries from 1803-1913.



from Cuba; but imports from this source ceased about 1870. The British Colonies contributed 5 per cent of the total, mainly from the Kapunda and the Burra-Burra mines, discovered in South Australia in the forties; while the United States' contribution of two per cent was derived almost entirely from the Lake Superior native copper mines, which began to produce in 1845.

For the next twenty years the consumption maintained a fairly uniform rate of acceleration, being about 85,000 tons in 1860 and 115,000 tons in 1870. The increase was met by an expansion of production in Chile, which now exported a considerable proportion of its copper in the form of metal (Chile bars) and regulus; whereas,

previously, high-grade ores had been sent to the United Kingdom for smelting at Swansea. The change was due to the high toll charged by the Swansea works, which drove the Chileans to establish their own local smelters. In 1870 Chile furnished half the total world's production, and thus became the leading producer. The United Kingdom occupied the second place, being followed in order by Spain and Portugal, the United States, Australia, Japan, and Cuba. In 1863 the United States produced 9 per cent and in 1868 10 per cent of the whole. The production of the United Kingdom was 15 per cent of the whole in 1863, decreasing to 9 per cent in 1868. On the other hand, that of the British Colonies rose from 7 per cent in 1863 to 10 per cent in 1868. This was in large measure due to the working of the rich oxide-ores of the Wallaroo and Moonta mines of South Australia, discovered in 1845; but the Great Cobar and other mines in New South Wales contributed, and Newfoundland began to ship ore from Tilt Cove in 1864.

In consequence of the increased demands of the engineering trades, especially in shipbuilding and marine engineering, followed later by the very extensive use of copper in electric power generation and transmission, the world's consumption of copper now began to rise more rapidly; by 1873 it was 122,000 tons per annum, in 1883 close on 200,000 tons, and in 1893, 310,000 tons. This rapid growth in consumption was met by large increases in the production of the United States and of Spain and Portugal: in Spain the Rio Tinto (taken over by an English company in 1876) enlarged its scale of operations and other pyrites mines in the Huelva district of Spain and the neighbouring territory of Portugal became great copper producers. In 1873 the order of contribution was as follows: South America (chiefly Chile), British Empire (17 per cent of the whole, Spain and Portugal (Rio Tinto and Tharsis), United States (13 per cent of the whole), Germany, Japan, and Russia. By 1883 the United States had passed the British Empire (the respective proportions being 26 per cent and 12 per cent), and from that period the production of the United States went up by leaps and bounds. This was brought about, not only by improving the methods of mechanical concentration and smelting, but also by very largely increasing the scale of operations, notably in the rich sulphide mines of Montana, in the native copper mines of Michigan (Lake Superior), and in the large porphyry contact deposits of Arizona.

During this period the output of the United Kingdom (one per cent in 1883) dwindled to insignificance, owing chiefly to the gradual deepening of the Cornish mines and the downward change from copper to tin which characterizes the lodes.[1] The contribution of the British Empire as a whole, however, showed a substantial increase in consequence of the important mining developments which then took place in Australasia, Canada, and South Africa.

[1] The present copper production of the United Kingdom is derived mainly from "precipitate" got by treating water from the old Parys and Mona mines in Anglesey.

The increase in the output of Australasia was due to the development of the Mount Lyell mine in Tasmania; that of Canada to the working of nickel-copper mines at Sudbury in Ontario, gold-copper mines at Rossland in British Columbia, and silver-copper mines at Nelson in the same province. In South Africa copper mines were worked by the Cape Copper Company and the Namaqualand Copper Company in Little Namaqualand, the ore being sent to Swansea partly in the form of matte, partly as a high-grade concentrate.

Table II gives the production of the world, the United States and the British Empire for every fifth year, from 1888 onward.

TABLE II.

Year.	World's Total.	United States.		British Empire.		U.K. alone.	Other countries.
	Tons.	Tons.	% of World's.	Tons.	% of World's.	Tons.	% of World's.
1888	262,000	103,000	39·1	24,000	9·3	1,456	51·6
1893	310,000	149,000	48·1	26,000	8·5	425	43·4
1898	442,000	239,000	54·0	34,000	7·7	640	38·3
1903	610,000	317,000	52·0	62,000	10·1	536	37·9
1908	790,000	427,000	54·1	79,000	10·0	579	35·9
1913	1,002,000[1]	555,000	55·2	91,000[2]	9·1	421	35·9
1918	1,395,000[2]	848,000[2]	60·8	—	—	182[3]	—

The order of production and the proportion produced by each contributor at the beginning of the twentieth century (1901) were as follows: United States (51½ %), British Empire (11½ %), Spain and Portugal (10 %), South America (8 %), Mexico (6 %), Japan (5 %), Germany (4½ %), Russia (1½ %), Norway (½ %), and Italy (½ %).

The total production of the world for the nineteenth century has been estimated [4] at 10,240,000 tons, the chief contributors being: the United States (29 %), South America (20 %), Spain and Portugal (13 %), the United Kingdom (8½ %), Japan (6 %), Germany (4½ %), Australia (4½ %), Russia (4 %), Norway and Sweden (2 %), Mexico (1½ %), Cuba (1½ %), South Africa (1½ %), Canada (½ %). The British Empire as a whole produced 16 %. (See Table III.)

The first decade of the twentieth century saw a production of 7,333,000 tons. During this decade the following countries practically doubled their production: United States, South America (where the biggest increase was in Peru), Mexico, Japan, and Norway. This great advance in production was largely brought about by improvements in the methods of mechanical concentration, which made it profitable to lower the grade of the material mined, and

[1] Merton. [2] *Mineral Industry.* [3] Home Office.
[4] By Nicol Brown & Turnbull in *A Century of Copper.*

thus to attack vast bodies of disseminated ore hitherto untouched, especially in the American States of Arizona, Utah, and Nevada. Other new producers were Serbia and German South-West Africa; Cuba also started work on its sulphide ores.

TABLE III.

THE PRODUCTION OF COPPER IN THE NINETEENTH CENTURY, ARRANGED ACCORDING TO COUNTRIES (STATISTICS DERIVED FROM NICOL BROWN AND TURNBULL'S "A CENTURY OF COPPER").

	Tons.	Tons.	Per cent.
UNITED STATES		2,993,540	29·3
SOUTH AMERICA.			
Chile	1,886,405		*18·3*
Bolivia	54,210		*·5*
Peru	34,135		*·3*
Venezuela	113,850		*1·1*
Total		2,086,600	20·2
BRITISH EMPIRE.			
United Kingdom	864,660		*8·5*
Australasia	470,219		*4·6*
South Africa	175,580		*1·7*
Canada	69,870		*0·7*
Newfoundland	46,527		*0·5*
Total		1,626,856	16·0
SPAIN AND PORTUGAL.		1,328,965	12·9
JAPAN		604,200	5·9
GERMANY		472,520	4·6
RUSSIA		420,920	4·1
SCANDINAVIA.			
Norway	103,500		*1·0*
Sweden	106,680		*1·1*
Total		210,180	2·1
MEXICO		142,360	1·4
CUBA		139,880	1·4
OTHER COUNTRIES		211,468	2·1
Total		10,239,489	100·0

The production of the present decade will exceed ten million tons, that is, it will be more than the whole production of the last century. The widespread use of the flotation method of concentration and the introduction of new processes for leaching the ores direct, brought fresh sources of supply into being at a time when production was being greatly stimulated by urgent war demands. With the coming of peace, however, a temporary fall in consumption was inevitable, and this began to show its effect on production in the year 1919, and will be accentuated in the present year (1920).

It is doubtful, however, whether consumption has reached its highest point. The ever-spreading use of electricity for power, light, and heat means a *per capita* increase of consumption throughout the world, especially in countries such as Russia and China, where hitherto electricity has not come into general use.

TABLE IV.

World's Production of Copper, according to Countries, for First Decade of Twentieth Century, derived from Home Office Returns.

Country.	1901. Metric tons.	1902. Metric tons.	1903. Metric tons.	1904. Metric tons.	1905. Metric tons.	1906. Metric tons.	1907. Metric tons.	1908. Metric tons.	1909. Metric tons.	1910. Metric tons.	Total 1901–1910.
United States	273,173	299,151	316,631	368,564	409,103	416,314	394,174	427,547	495,760	489,957	3,890,374
British Empire	(63,874)	(52,208)	(61,865)	(64,395)	(70,947)	(73,421)	(75,267)	(78,705)	(72,704)	(78,914)	692,300
Australia	29,500	25,128	31,410	29,765	35,280	38,771	41,103	38,220	37,680	41,060	
Canada	18,575	17,767	19,632	19,491	21,590	25,868	25,640	28,895	23,811	25,262	
Cape Colony	12,443	6,120	7,523	10,654	10,397	5,121	5,631	87,746	8,606	10,415†	
Newfoundland	2,799	2,703	2,753	3,984	2,859	2,688	1,700	1,567	1,155	1,480	
Sundry	557	490	547	501	821	973	1,193	1,277	1,452	757	
Spain and Portugal	(60,625)	(58,894)	(63,058)	(67,541)	(57,637)	(69,950)	(73,061)	(69,160)	(77,087)	(75,387)	672,400
Spain	54,625	52,417	56,150	60,565	53,120	62,290	64,731	65,625	71,747	71,747	
Portugal	6,000	6,477	6,908	6,976	4,517	7,660	8,330	3,535	5,340	3,640	
South America	(39,070)	(37,900)	(42,723)	(41,427)	(45,895)	(46,328)	(52,377)	(64,816)	(65,176)	(72,677)	508,389
Chile*	30,570	26,600	29,086	29,923	29,605	29,626	28,863	42,096	42,726	42,726	
Bolivia	—	3,600	4,141	2,000	4,045	3,288	2,813	2,039	2,470	2,478	
Peru	8,500	7,700	9,496	9,504	12,213	13,474	20,681	20,681	19,854	27,347	
Venezuela	—	—	—	—	32	—	20	— —	126	126	
Mexico	37,000	43,312	48,976	77,820	69,500	61,600	80,330	43,940	59,780	80,000	602,258
Germany	31,376	30,578	21,782	22,502	24,480	22,000	22,858	22,790	24,719	29,000	252,085
Japan	25,304	27,440	33,245	35,560	33,715	38,515	40,183	41,399	45,793	50,705	371,859
Russia	8,258	8,258	8,817	10,700	8,840	10,424	14,632	16,850	18,421	22,700	127,900
Italy	4,855	4,685	4,344	5,503	4,731	5,232	7,114	3,614	3,174	4,526	47,778
Norway	4,684	4,996	4,180	5,701	7,200	7,613	8,585	7,134	9,900	9,570	69,563
German S.W. Africa	—	—	—	—	—	26	3,804	6,058	6,671	6,482	23,041
Serbia	—	—	—	—	—	763	1,764	2,198	4,209	5,335	14,269
Cuba	—	—	—	2,045	1,825	1,017	1,912	—	4,146	1,896	12,841
Remaining countries.	5,490	4,430	4,364	3,620	4,329	3,159	5,894	6,027	5,171	5,314	47,798
Total	553,709	571,852	609,985	705,378	738,202	756,362	781,955	790,238	892,711	932,463	7,332,855

* Including Bolivia.

† South Africa.

The vital question is whether production will be able to meet such heavy demands as are here foreshadowed in view of the approaching exhaustion of some of the existing sources of supply. While the number of companies contributing to the world's production is well over three hundred, about half the total is derived from a score of mines only. Many of these big producers are in America. The United States contributes from its mines in Arizona, Montana, Michigan, Alaska, Nevada, New Mexico, and California over 60 per cent of the world's production; and there are big producers in Canada (Sudbury), Mexico (Cananea, Nacozari, Boleo), Chile (Chuquicamata), Peru (Cerro de Pasco), and Venezuela (Aroa). Japan also has some great mines (Ashio, Besshi, Hitachi, and Kosaka), and the Rio Tinto in Spain, the Mansfeld in Germany, and the Bogoslovsk, Dzansoul, Kyshtim, Sissert, and Spassky mines in Russia should be noted in this connexion. Although existing reserves may be large enough for the immediate future, it is quite certain that some of these large mines cannot have a very long life, and their shutting down would appreciably affect production unless fresh discoveries enable their places to be filled.

The copper recovered from the ore mined throughout the world probably does not exceed 45 lb. to the long ton or two per cent. Exact figures are forthcoming for the United States: in 1906 the average yield for all ores treated was 2·5 per cent; in 1903 it had fallen to 1·67 per cent, and by 1914 to 1·6 per cent; in 1916 it was 1·7 per cent.[1] There is, consequently, not the margin for increasing the available reserves by lowering the grade of the ore mined, such as obtains in iron-ore mining; and any increase in the supply of copper, or, indeed, the maintenance of the present rate of production, must depend in the long run either on the discovery of new deposits, or on the improvement of the treatment methods. During the last decade the world has been searched for new occurrences of copper-ore, and it is certain that the efforts of capitalists and mining engineers will not be relaxed in that direction. Metallurgists also will perfect the existing methods of extraction or find new ones whereby the yield will be increased. B. S. Butler states[2] that from 5 to 30 per cent of the copper content of the ore at present treated is lost, and if this be so there is room for improvement in this direction.

The United States, by its refineries on the Atlantic seaboard, controls a large proportion of the South American and Canadian output of the metal. Acting in conjunction with the large home production, the effect of this control has been to place the copper market of the world (which for the greater part of the nineteenth century was centred in Great Britain) practically in the hands of the United States. It may be that in view of an increasing consumption the copper magnates who control this market will use their power to limit supplies and drive up the price of copper. These

[1] *The Mineral Resources of the United States*, 1916, p. 642.
[2] *The Strategy of Minerals*, New York, 1919, p. 153.

considerations lead some to foretell a coming world shortage which will be little less than a famine.[1]

On the other hand, great reserves of unworked copper-ore undoubtedly exist in different parts of the world, and in course of time an increased production may be looked for from the resources of Mexico, Chile, and Peru in Central and Southern America, from the Altai, the Kirghiz Steppes, and the Urals in Russia, from the Belgian Congo in Central Africa, and from South-West Africa.

Whether future supplies will equal the demands there are not sufficient data at hand to determine.

The Representation of Stratigraphical Divisions by Shading.

By Dr. J. W. Evans, F.R.S.

BLACK and white shading is frequently employed in geological maps and sketches, but there is a remarkable absence of uniformity in the means by which different strata have been represented.

There are three purposes for which shading may be employed in geological maps, but these cannot as a rule be satisfactorily effected on the same map. It may be desired to express (1) the lithological characters of the rocks, (2) their stratigraphical position, and (3) their structural relations. For the first purpose it is convenient to use the same conventional shading as is employed in diagrams of sections. It is mainly with the second that I shall deal in the present article. For the third purpose little has yet been done, and I hope to consider the subject on another occasion.

I devised the system of denoting the different divisions of the geological succession, which I shall now describe, for the small scale geological maps published in the portion of the *Handbuch der regionalen Geologie* dealing with the British Isles. One of these is reproduced on a reduced scale in this issue of the Geological Magazine. The geological boundaries were drawn by Dr. Morley Davies and the shading by Miss Reeks, Technical Artist to the Imperial College of Science and Technology.

In this system the pre-Cambrian rocks are distinguished by a north-east and south-west direction of shading (the Charnian strike), the older Palæozoic—Cambrian, Ordovician, and Silurian—by a north-east and south-west direction, the later Palæozoic—Devonian, Carboniferous, and Permian—by a north and south direction, that of the Pennine range, and the Mesozoic by an east and west direction (Hercynian).

The Kainozoic is indicated by crosses and the Quaternary or Anthropozoic by small circles or "birds" (ᵔᵔ). In the subdivisions of the strata expressed by each direction of shading, the older rocks are distinguished by continuous lines and the later by

[1] Sidney Brooks in the *North American Review*.

interrupted lines and the intercalation of dots. Further subdivisions can be distinguished by the spacing of the shading, variations in the number of dots, and other devices. In the Kainozoic, the Eocene and Oligocene are shown by diagonal crosses and the Miocene and Pliocene by upright crosses. The Eocene and Oligocene can be distinguished by the opposite or alternating arrangement respectively of the crosses and a similar distinction can be made between the Miocene and Pliocene. Here, again, numerous means can be devised by variations in the forms and relations of the crosses to express minor divisions.

Passage beds, or those in which the outcrops of different strata are too much involved to be separately mapped, may be indicated by a combination of two shadings. The usual symbolic shading for lithological characters can also be combined with this method of shading.

The occurrence of volcanic rocks is indicated by a thickening of the shading. Intrusive rocks are shown in black, or if it is desired to express their age this may be effected by the same shading as that employed for sedimentary rocks but reversed, that is to say in white on black.

REVIEWS.

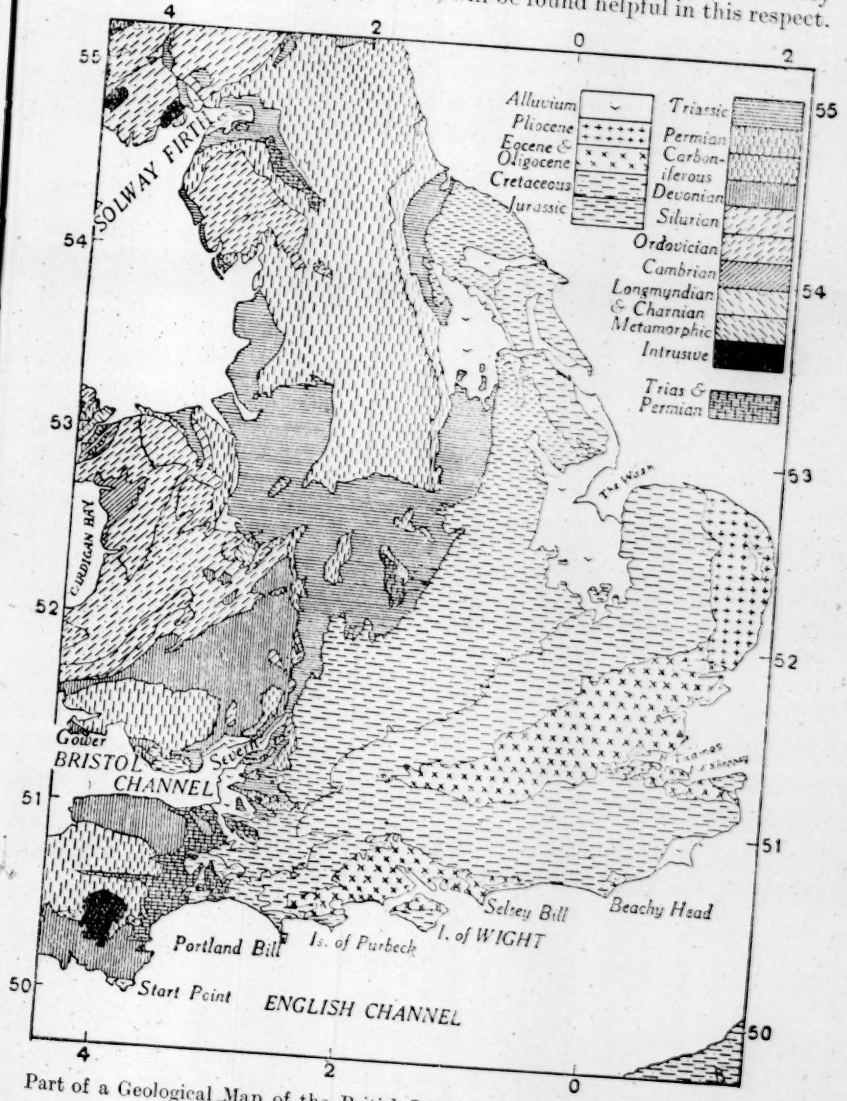
THE BRITISH ISLES. By P. G. H. BOSWELL, G. A. J. COLE, A. M. DAVIES, C. DAVISON, J. W. EVANS, J. W. GREGORY, A. HARKER, O. T. JONES, P. F. KENDALL, L. RICHARDSON, W. W. WATTS, H. J. O. WHITE. Local Editor: J. W. EVANS. With an Appendix: THE CHANNEL ISLANDS. By F. PARKINSON. Handbuch der regionalen Geologie, vol. iii, pt. i, 354 pp., with 73 figures. Heidelberg: Carl Winters Universitätsbuchhandlung. 1917.

THIS valuable work forms the first section of the third volume of the *Handbuch der regionalen Geologie*. The manuscript appears to have been completed by 1914, but the War delayed its publication, and the date of issue is given on the cover as 1917. Even now it is difficult to procure the volume in England.

The first twenty-four pages are devoted to the Morphology of the British Isles, England and Wales being dealt with by Dr. A. M. Davies, Scotland by Professor Gregory, and Ireland by Professor Cole. Then follows a short note on British Earthquakes by Dr. C. Davison, and the remainder of the work, more than 300 pages, is devoted to stratigraphy. All the sections relating to Ireland are written by Professor Cole, and in most of the geological systems the igneous rocks are discussed by Mr. Harker. In the case of the Ordovician and Silurian systems, however, the volcanic rocks are described along with the sedimentary deposits, while the intrusive rocks are dealt with separately by Mr. Harker. With regard to the other sections, Professor Gregory describes the pre-Cambrian of Scotland, Professor Watts the pre-Cambrian of England and Wales and the Cambrian and Ordovician of Great Britain; Professor O. T. Jones takes the Silurian, and Dr. Evans the Devonian, while Professor Kendall is responsible for the Carboniferous, Permian, and Quaternary. The Trias and Rhætic, in accordance with German custom, form two distinct sections, which are written by Mr. Linsdall Richardson and Professor Boswell. The Jurassic and Lower Cretaceous are dealt with by Dr. A. M. Davies and Professor Boswell, and the Upper Cretaceous and Tertiary by Mr. Osborne White. Finally there is an appendix on the Channel Islands by Mr. Parkinson. In the GEOLOGICAL MAGAZINE it is not necessary to add that these names are a sufficient guarantee of accuracy.

The space allotted to morphology is too small to allow of an adequate treatment of so complex a subject; but the stratigraphical section is a very complete account of British stratigraphical science as it was a year or two before the War. It is approximately on the same scale as Jukes-Browne's *Stratigraphical Geology*, but local detail is not so strongly emphasized as in that work. It is not that the local detail is omitted, but that it is more subordinated

to the general description and is not accentuated by heavy type. For this reason the book is in general easier and more interesting to read, but it is not quite so handy for occasional reference. The very full correlation tables, however, will be found helpful in this respect.



Part of a Geological Map of the British Isles, reproduced on a reduced scale from the *Handbuch der regionalen Geologie.*

The number of pages given to the pre-Cambrian and Palæozoic rocks is 171, while the Mesozoic and later formations occupy 132. A work of this kind is not a complete presentation of facts, but a presentation of facts so far as they are known; and judged on this basis the space devoted to the older rocks is disproportionately large. But perhaps this is unavoidable. A system which occurs in widely scattered outcrops may require more room for its description than a system which forms a continuous belt, although—and, indeed, it may be *because*—our knowledge of the former is much less complete.

It would evidently be impossible, without unduly extending this notice, to criticize the entire book in detail; and it would be invidious to select the work of any single author. It must accordingly suffice to say that the whole scheme is admirably carried out, and that errors are few and, within the limits of our present knowledge, unimportant. Exception, however, may be taken to a statement on the first page. According to Dr. Morley Davies, the terms Caledonian and Armorican, as applied to folds, merely denote direction. In making this statement he follows Professor Lapworth, who at a meeting of the Geological Society in 1902 gave a similar definition. But this is not the meaning of the terms as originally proposed, nor is it the sense in which they are now used by most geologists, or, indeed, by any geologist outside the British Isles. The English language is not so poor that it requires the invention of special terms to indicate direction, and direction only; though some convention is desirable to avoid such clumsy expressions as "N.E.–S.W. folds". If, however, the geologist cannot prevail upon himself to use so simple a word as north-east, he should at least select an adjective which is not already employed in the same connexion, with a different significance.

The book is not intended for the novice, but the advanced student will find it very useful. For the trained geologist it may to a considerable extent take the place that H. B. Woodward's *Geology of England and Wales* used to occupy, though it is entirely different in conception and execution.

Useful bibliographies are appended to each system. They vary in completeness, and most of them seem to end about 1912; but some include references to papers published in 1913 and 1914. Most of the figures are from previous publications, but some of the maps and diagrams have been specially prepared. All of them are clear and well reproduced. One of the original maps is here reproduced on a reduced scale. A first glance revealed rather a large number of misprints, but this must have been by chance, for closer examination showed that the proportion of printers' errors is small. There is, in fact, no fault to find with the manner in which the book has been produced, and both editor and publisher may be congratulated. It should perhaps be added that the volume is in English. The price given on the cover is 16 marks, but what that may mean now no one but the publisher is likely to know. P. L.

THE INFLUENCE OF MAN ON ANIMAL LIFE IN SCOTLAND: A STUDY IN FAUNAL EVOLUTION. By JAMES RITCHIE, M.A., D.Sc., F.R.S.E., Assistant Keeper in the Natural History Department of the Royal Scottish Museum. pp. 550. Cambridge University Press, 1920. Price 28*s.* net.

THIS book makes a strong appeal to the naturalist and the archæologist, as well as to all who are interested in the early history and development of Scotland. The author selected that country as the basis of his investigations, not simply because it lay close at hand and afforded comparatively easy opportunity for study, but for the far more important reason that Northern Britain, when the ice-sheet which exterminated all animal life receded, was not subjected to disturbing factors which elsewhere have complicated the problems of interaction between different groups of organisms and their environment. Dr. Ritchie draws an instructive and fascinating picture of the rich Scottish fauna which existed in the time when post-Glacial man arrived after the old Stone Age of England. He describes the reindeer and elk and the other kinds of deer, all of gigantic size as compared with their living representatives, the wild horse, ox, sheep, and boar, the lynxes, bears, and wolves, and many other species which have long since been exterminated by man. He presents evidence as to the origin and history of the domestic animals as well as other information of interest to the geologist; in particular we must mention the account he gives of the lower and upper forests of the peat. The book is enriched by some of Dr. Ritchie's own observations, as where he describes the remains of the cat dug up at Dunagoil, in Bute. (Since there was a prehistoric settlement there, could this animal have belonged to a domesticated variety?) The bones found were much larger than those of the modern wild-cat, and the inference is that this animal, like so many Scottish species, has diminished in size as man's influence increased. The book contains a wealth of information admirably presented, and the illustrations, some of which are by the author himself, are of a high order of excellence. There are also some useful maps, showing the distribution of certain animals at different historical periods.

F. H. A. M.

DIE STÄMME DER WIRBELTHIERE. By O. ABEL, Professor of Palæobiology at Vienna. xviii + 914 pp., with 699 figures. Berlin and Leipzig: W. de Gruyter & Co. 1919. Price 56 marks unbound, 62 marks bound.

THIS work is primarily a textbook of vertebrate palæontology, but recent forms are referred to for purposes of comparison and classification. The book opens with a table setting out all the extinct and living families, and the classification here adopted is followed throughout the work. There is a short introduction dealing with various theoretical considerations and the meaning of

the terms "species", "variety", etc. This is succeeded by remarks on the anatomy and on the physiological significance of the skeletal structures with their primitive relations. The classification differs considerably from that of Smith Woodward. Thus, excepting for the Cyclostoma, all the primitive vertebrates (Osteostraci, Antiarchi, etc.) are included among the Pisces. *Palæospondylus gunni* is regarded as a larval Arthrodiran (perhaps *Coccosteus*) of Dipnoan affinities. The classification of some of the higher forms is apt to be conservative, and the Anomodonts are included among the Reptilia. It is to be regretted that some of the recent South African work on this subject was published too late to be noticed. It is a pity also that the scope of the book did not admit of discussions on the multiple origin of some of the domestic animals, for the phylogenetic development of these is hardly touched on. British authorities are, however, freely quoted, and most papers published up to the time of the War are duly referred to. The value of the work is enhanced by the inclusion of accounts of the author's own investigations on the Sirenia and Cetacea. The figures are both numerous and in the main excellent, and a number of these are from English sources, which are duly acknowledged. In view especially of the difficult conditions under which the book must have been completed, its issue is a great credit both to author and publishers. There are four valuable indices, of morphological terms, of classes, orders, etc., of genera, and of authors quoted. F. H. A. M.

Reminiscences of my Life. By Henry Keeping. Second edition. pp. 24. Printed and published by F. W. Talbot, 17 Sussex Street, Cambridge. Price 2*s*. 6*d*.

In reading these "Reminiscences" our regret is that they are not longer. Written by a geologist who has lived under five reigns, who was for nearly half a century Curator of the Museum of Geology at Cambridge, and who has spent much time in the company of distinguished men, this little work possesses a deep human interest. Mr. Keeping begins by telling us of his early life in the region of the New Forest and the Isle of Wight; he describes how he first came to study geology, and how his interest in the subject grew and was strengthened by those who became his friends. We get glimpses of great geologists long since departed, as well as reminiscences of other famous men, such as Dr. Whewell, Professor Henslow, and Sir Richard Owen, and we read how the author as Curator of the Museum came into close touch with Adam Sedgwick, the Woodwardian Professor, concerning whom he narrates some amusing anecdotes. Of the great amount of work which Mr. Keeping has done, we are able to form a slight idea, and we could have wished for a less fragmentary account of his numerous investigations in the field. Nevertheless, we are grateful to him for this interesting record of some of the incidents of his busy life, and we hope that in a third edition he may tell us more. F. H. A. M.

REPORTS AND PROCEEDINGS.

Edinburgh Geological Society.

November 17, 1920.—Mr. E. B. Bailey, M.C., B.A., F.G.S., F.R.S.E., President, in the Chair.

"Recent Advances in Highland Geology." An Address by the President, Mr. E. B. Bailey, M.C., B.A., etc.

There is good reason to believe that the rocks of the S.W. Highlands are assignable to three major structural divisions, which in descending order are as follows :—

Loch Awe Nappe.
Isltay Nappe.
Ballappeil Foundation.

The Loch Awe Nappe is only preserved in the heart of the Loch Awe Syncline.

The Isltay Nappe outcrops in the Islay Archipelago and in the district reaching from Kintyre to Loch Tay. The connexion between these two outcrops is locally severed by the Etive Granite.

The Ballappeil Foundation emerges from beneath the Isltay Nappe in an extensive district ranging N.E. from Lismore and Glen Orchy. It takes its name from Ballachulish, Appin, and Loch Eilde.

The two lower structural divisions are themselves structural complexes. Thus a great recumbent fold has been recognized in Ben Lui within the limits of the Isltay Nappe. This Ben Lui Fold, with an associated thrust at the base of the overlying Loch Awe Nappe, leads to a marked contrast of the two flanks of the Loch Awe Syncline below the level of the Ardrishaig Phyllites.

The Loch Awe and Isltay Nappes seem to have travelled into position from the N.W. The reverse movement, so well known in the N.W. Highlands, is, however, exemplified by later disturbances, including the Loch Skerrols Thrust of Islay.

The interpretation of the S.W. Highlands, as sketched above, has much in common with Clough's reading of the Cowal district, which itself constitutes an important part of the region considered.

Liverpool Geological Society.

November 9, 1920.—W. T. Walker, Esq., B.Sc., F.G.S., in the Chair.

Paper: "A Contribution to the Microscopic Study of the Carboniferous Limestone of North Wales." By T. A. Jones.

The Carboniferous succession in North Wales is probably unrepresented by any beds earlier than those of the Upper Seminula zone. The limestones are almost entirely of organic origin, and are built up of the remains of crinoids, corals, polyzoa, foraminifera, brachiopod and other shells, cemented by a varying amount of clear secondary calcite. Occasionally some of the beds consist